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THE MEASUREMENT OF HIGH TEMPERATURE BY THE ELECTRICAL RESISTANCES OF PLATINUM, INCLUDING A DESIGN OF AN ELECTRICAL PYROMETER.*

BY W. A. EBSEN AND E. W. FRAZAR.

THE accurate measurement of temperature, especially high temperature, has ever proved to scientists a most difficult problem. There has existed ever since the birth of science a requirement for the measurement of the intensity of heat. Many and various methods have been discovered, and for a long time were found to be sufficiently accurate for the low temperature then in use. But as science progressed, and the arts were developed, the measurement of high temperature became a necessity, and the old forms were found to be quite useless. As early as the beginning of the eighteenth century the attention of physicists was turned in this direction. Since then the different methods and instruments suggested for this purpose have been numerous, in fact, the variation of almost every physical property of substances, which alter with changes of temperature, has been utilized with more or less success, such as the expansion of metals, graphite, clay, the saturation pressures of vapors of various liquids, the pressure of gases disassociated from various solids, the electromotive force of a thermo-electric couple, the expansion of air, melting points of solids, calorimeter methods, measurements of

* Abstract of Graduating Thesis, June, 1890.

changes in electrical resistance of metals, density of vapor of liquids, change of shape of a spiral of different metals, alteration in wave length of a note of given pitch, spectrum analyses, etc.

At the present time the extremely high temperature used in the arts, such as in blast furnaces, potteries, etc., necessitates more accurate knowledge of the degrees of temperature of a furnace, but the known methods do not seem to give sufficient precision.

SYNOPSIS OF THE MORE FAMILIAR METHODS.

In 1701 Newton gave some results to estimate the temperature of red-hot iron by noting the time it required to cool to an observed temperature, assuming his law of cooling.

At about the same time an experiment was made in Paris, in which the temperature of a red-hot bar of iron was determined by means of a rude air thermometer, the first of its kind, in which variations of atmospheric pressure were allowed for.

The Expansion of Liquids is the most favored form, but is adapted to low temperatures only.

The Expansion of Solids. — The best form of this kind of pyrometer is that devised by Daniell. It consists of a prismatic bar of platinum placed in a prism of plumbago. Upon the platinum bar rests the lever arm of a recording device. The apparatus is placed in melting ice, and the position of the pointer noted. It is then placed in the furnace, and when the platinum reaches a constant temperature a reading is taken. The temperature is calculated from the established laws of linear expansion of platinum. This form can be used where only rough approximations are desired, as it is not suitable for delicate determinations.

Contraction of Baked Clay. — This method was devised by Wedgewood, to determine the temperature of his pottery kilns. He noticed that when clay is baked it contracts considerably, the amount of contraction increasing with the temperature. On this principle he based the construction of his pyrometer. He made cylinders of clay, all having the same diameter. These were placed in the furnace, and after reaching the temperature of the same, they

were removed, allowed to cool, and placed in a template having sloping sides, one of which was graduated in degrees. The amount of contraction, as shown by the scale, gave the temperature. This method is, evidently, very crude.

Expansion of Air.—Theoretical and experimental investigations show that equal increments of heat produce almost exactly equal increments of pressure in a perfect gas, if the volume is kept constant, or conversely, if the pressure be constant, equal increments of volume. Air is so nearly a perfect gas that it has been used for this purpose. This method is the only one known to give results which can be depended upon, and is used as a standard in the graduation of nearly all the other pyrometers. It is often asked—"Why not use the air thermometer for every case?" The answer is to be found in the fact of the great difficulty of using it, its bulkiness, variation with atmospheric pressure, and numerous necessary corrections.

There are two methods of using it, the method of constant pressure and of constant volume. The first method, as used by Regnault, consists in introducing in the source of heat porcelain bulbs having fine, drawn-out necks, open to the atmosphere. When these have assumed the desired temperature, the neck is closed by a blowpipe, cooled and weighed. They are next placed under water and the necks broken.

The air having been expanded by the heat of the furnace is rarefied and draws in water. Another weighing is taken and the gain in weight gives data from which the temperature can be computed. This method has many disadvantages and is but seldom used.

The method of constant volume gives continuous variations of temperature. The most convenient form is that devised by Jolly (see Poggendorf's Jubelband, page 82, 1874). It consists of a bulb of hard glass or porcelain having a fine neck or tube connected with a long manometer tube of rubber strengthened by linen coverings. The reservoir end of the manometer is fixed to a support which may

be moved vertically along a pillar. A scale is placed on the pillar, and a vernier on the slider furnishes the means for accurate readings of variations of pressure in the bulb. The bulb is subjected to heat, and the desired temperature obtained by reading the pressures as given on the scale and making corrections for the barometer and thermometer.

The calorimeter method consists in determining the amount of heat given out by a mass of platinum, copper or wrought iron, cooling in water from a high temperature. The temperature is deduced by a formula which takes into account the specific heats of the metals. This method is very extensively used, and is very convenient for determining the temperatures of furnaces. The chief disadvantage of this method is the uncertainty as to the specific heats at high temperatures of the bodies employed.

The melting points of various alloys of known composition has been suggested as a means of finding temperature. Oxidation and molecular changes, however, are liable to occur and prevent precision.

The changes produced by heat in the electro-motive force of a thermo-electric couple has been used with partial success. For low temperatures it is extremely sensitive and quite accurate, but its range is very limited. (Tait, Edinburgh Phil. Trans. Vol. XXVII., p. 27.)

It appears from the observations of many experimenters that very slight changes in physical state or chemical composition will greatly vary readings.

Spectrum Analysis.—One of the most modern steps in pyrometry is the attempt to measure temperature by the light a body emits. The spectroscope is brought into use, but very little has been done as yet in the way of experiments.

Siemens Pyrometer (Proc. Roy. Soc., 1871, p. 443). The principle of this pyrometer is the increase in the electrical resistance of a platinum wire caused by heat. The platinum wire is coiled on a porcelain cylinder and inserted in the source of heat. The resist-

ance is measured by a form of differential voltameter. This is a very good form but is liable to error, as the method of electrical measurement is not accurate. It depends on the decomposition of water and sulphuric acid.

It is a well known fact that when certain metals are heated their electrical resistances undergo very considerable changes. These changes are perceptible for even extremely small increments of heat, and it is believed by scientists generally (and later experiments seem to warrant these assumptions) that there exist certain laws of variation which, though probably differing slightly for different metals, yet follow a somewhat general rule. If these laws can be exactly established, it is perfectly reasonable to conclude that with the present perfected means of electrical measurements this will afford a means of measuring high temperatures. Platinum is a metal which seems to be specially adapted for this purpose. Its infusibility, its non-oxidizing properties, great range of electrical resistances with varying temperatures, all seem, at the present time, to render it far superior to any other metal.

Experiments have been made with the object of establishing the practicability of utilizing this metal as a thermometer and pyrometer, but so far the published results do not seem to be sufficiently conclusive to warrant its use. The literature on the subject seems to be meagre and unsatisfactory, and consists mostly of mathematical discussions and assumptions founded on but few physical experiments. Moreover, these experiments have been made at comparatively low temperatures only and the methods used appear very liable to error, especially the measurements of electrical resistances. However, with the recent additions and improvements in electrical science it seems possible that most of these errors may be eliminated. In the experiments above mentioned the standard of comparison was the air thermometer, this being the only accepted standard of measurement of intensity of heat.

The writers intended, at first, to establish, as far as possible and by the most careful and accurate experiments, the curve showing

the relation between temperatures and resistances of platinum. Having determined this curve it was proposed to compare it with the formulas given by well-known physicists, and, should they coincide approximately, to extend the curve indefinitely and thus establish a means of measuring very high temperatures; or, if not coinciding, to form an empirical law. But as the experiments progressed many unforeseen complications arose which will be found explained further on.

For convenience, the platinum used was taken in the form of small wire. The sample was supposed to be the purest obtainable, and refined especially for electrical purposes.

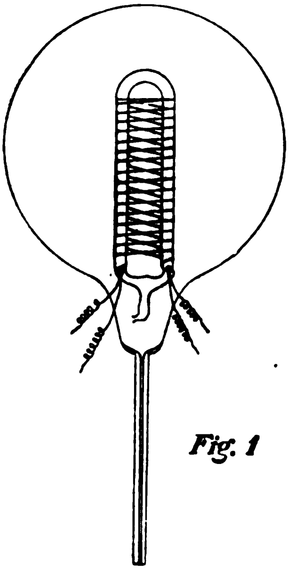


Fig. 1

The standard of comparison was the air thermometer (method of constant volume) as this is the only form of thermometer known to give accurate results for low as well as high temperature. In order to eliminate errors of comparison between resistances of the platinum wire and the air thermometer, the idea was suggested of making a coil of the wire and placing it directly within the bulb of the air thermometer. It was afterwards found that this same method

had been used by Callendar in his experiments made at the Cavendish Laboratory, in Cambridge, England (Proc. Royal Soc. Vol. XLI., p. 231).

The bulb of the air thermometer used (see Fig. 1), was made of German glass 6 inches in diameter. The neck terminated in an 8-inch heavy glass capillary tube. Within the bulb was placed the platinum coil. The latter was made of the sample of platinum drawn down to a very small wire (about 38 S. W. G.) About 7 feet was coiled on a U of glass tubing supported within the bulb. (The coil was made of a loop, like a shunt, to prevent any induced currents.) The four terminals were further lengthened by short pieces of copper wire, carefully soldered, and protected from each other by pieces of fine glass tubing.

The barometer used was a standard form made by James Green (New York), which, by means of a vernier, could be accurately read to the $\frac{1}{1000}$ of an inch. The cathetometer, used to determine heights and levels, was made by J. Salleron (Paris).

To secure constancy in the temperature of the air within the bulb of thermometer, the following plan was adopted. First the bulb was placed in an iron box and the tubes were led out through an opening stuffed with asbestos; surrounding this was placed a second iron box, leaving considerable space between the two. Next these were protected by a felt covering and a wooden box casing.

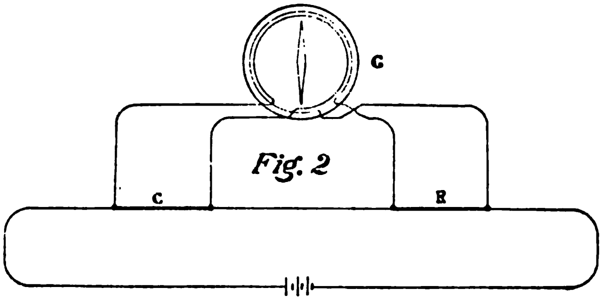
Heat was furnished for low temperatures by a Bunsen burner, controlled by a pinch cock, and the heat distributed by an asbestos pad. Higher temperatures were obtained by a form of gas furnace.

A "Thompson's high resistance astatic galvanometer" was employed, and the resistance boxes gave a range of from 1 to 5,000 ohms. By the addition of a slide-metre bridge it was possible to read accurately to .00001 ohms.

In setting up the air thermometer the greatest precautions were taken to insure the bulb being filled with perfectly dry and pure air. To do this the bulb was first washed with distilled water and connected with the air pump and drying tubes by a three-

way cock. The bulb was exhausted and filled with air drawn through the tubes a great number of times. The manometer, still disconnected from the bulb, was now filled with mercury which had previously been carefully cleaned. The connection of the bulb filled with dry air and the manometer was by heavy rubber tubing, the joint being protected by binding with wire and a covering of shellac. The results at first obtained showed great irregularities, due to leakage at this joint. This difficulty was, however, overcome by means of a special form of cement obtained through the kindness of Professor Mayer.

A simplified diagram of the connections necessary to measure the resistance of the coil by the method of fall of potential and comparison by the differential galvanometer is given in Fig. 2, in which



C represents the coil in question, and R is the standard resistance, which may be varied at pleasure to determine any changes in the resistance of C. The main current passes through both the coil and the standard resistances. From the terminals of *C* and *R* the galvanometer coils are connected and the current is thus shunted off into the galvanometer in such a manner that the current passes in opposite directions through them. If the resistance of *C* and *R* are equal the needle will remain at o, but should *C* change by some variation of temperature the needle will be deflected. By increasing or decreasing *R* the needle may be brought back to o, and the amount of increase or decrease of *C* thus measured.

By this method are eliminated all previous errors caused by heating of connecting wires, and the high resistance of the galvano-

meter coils (3,000 ohms) themselves does away with any inequality in the resistances of the connecting wires or connections.

To calculate the temperatures by the air thermometer it is necessary to know the differences of level of the mercury in the two legs of the manometer. To do this the marks on the two reservoirs were brought to the same horizontal line by means of the cathetometer and a reading of the vernier of the air thermometer scale taken. This level is the basis from which the calculations are made, since a rise of the mercury above this point produces compression, and below, a tension on the air in the bulb. This level reading must be corrected for capillary depression.

To calculate the temperatures, we have

$$t = \frac{H_t - H_o}{AH_o - KH_t}, \text{ in which}$$

$t =$ Temp. Cent.

$H_o =$ Pressure to which air in bulb is subjected at 0° C. $= (h_o \pm b_o)$ where

$b_o =$ Height of barometer in mm. reduced to 0° C.

$h_o =$ Differences of level of mercury in manometer at 0° C.

$H_t =$ Pressure to which air is subjected at t° C. $= (h_t \pm b_t)$ where

$h_t =$ Height of barometer in mm. reduced to t° C.

$b_t =$ Difference of level of mercury in manometer at t° C.

$K = .000025 =$ co-efficient of cubical expansion of glass.

$A = .003665 =$ co-efficient of expansion of air.

To reduce the barometer readings to θ° C., we have

$$H - \frac{m\,(t-T) - b\,(t-o)}{1 + m\,(t-T)} = \text{reduced height in inches,}$$

in which

$h =$ observed height.

$t =$ temperature of attached thermometer in Fahr. degrees.

$T =$ temperature to which observed height is to be reduced.

$m =$ expansion in volume of mercury $= .0001001$.

$l =$ linear expansion of brass for 1° Fahr. $= .0000104344$.

$\theta =$ normal temperature of the standard scale $= 62$° Fahr.

This gives height in inches and 32° Fahr. To reduce to mm., at 0° C., divide by .03937079.

In the second set of experiments an air thermometer of a special shape, as shown in Fig. 3, was used. It was made of hard combustion tubing about 24 inches long and 1½ inches in diameter, well adapted to high temperatures and corresponding pressures.

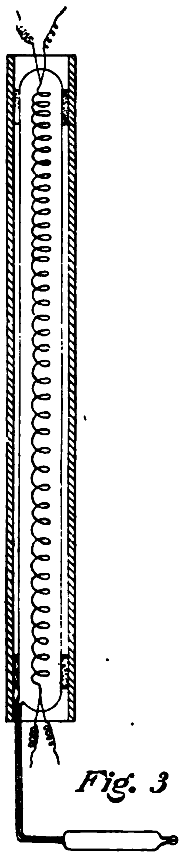


Fig. 3

The platinum wire used in this case was larger (32 S. W. G.), and of about the same length (six feet).

It was coiled in a spiral, and inserted as shown in the figure. The capillary neck and reservoir of the manometer formed a portion of the thermometer bulb itself, thus avoiding the previous error of a joint. A wrought-iron tube of 2¼ inches diameter was placed around the whole up to the neck of the capillary tube and supported by asbestos packing. The ends were also packed with asbestos. This made a spacious air bath, and ensured great constancy of temperature.

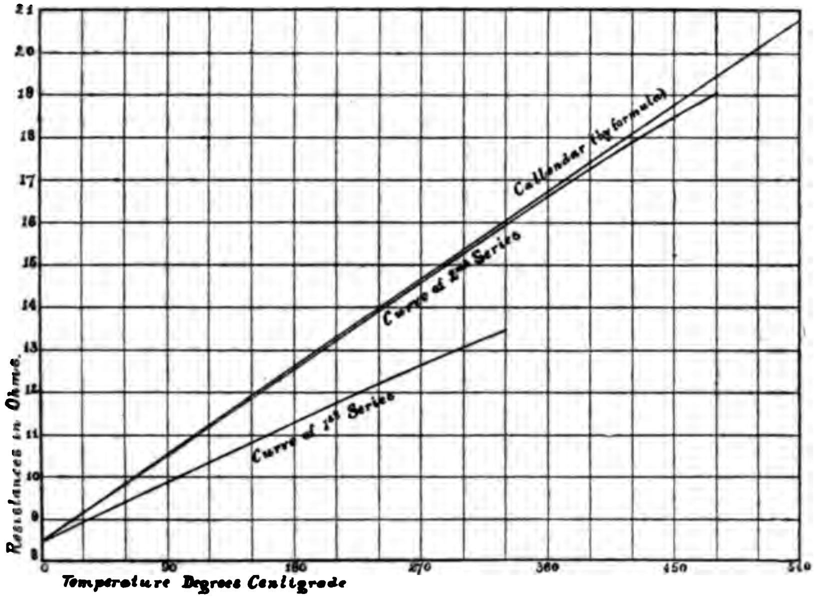
The furnace used in this set of experiments was a modified form of Bunsen's Combustion Furnace.

The results of the experiments were plotted, the curves obtained being shown in the accompanying plate. It will be noticed that there is a considerable difference in the direction of the curves, which would indicate that the two samples of platinum must have been of different composition. Had they been both of absolutely pure platinum they would have agreed (considering, of course, the proportionality existing between their lengths and cross-sections).

The original intention of establishing one standard curve was, therefore, abandoned. But it still remains practical to use platinum

as a pyrometer if the wire used be taken from a sample which has been standardized.

It was noted that up to the highest temperatures used (1,300° Fahr.) during the experiments the platinum did not appear to undergo any changes. It would always return to low temperatures and give correct resistances as checked by the air thermometer. The curve for absolutely pure platinum would prove of the greatest



interest to physicists, but can hardly be of practical use as a standard of pyrometry, as it is almost impossible to procure pure platinum. The very smallest trace of impurity would seriously affect its resistances.

The curve plotted in the accompanying plate, for low temperatures, is, approximately, a straight line, confirming the statements of Siemens, Callendar, Matthiesen, etc., that for comparatively low temperatures the resistance varies directly as the temperature.

At higher temperatures it gradually falls away, curving downwards, showing that the temperature increases more rapidly than the resistance.

As the above experiments seemed to be very satisfactory, it was thought advisable to design a pyrometer of a form convenient for practical use, embodying the principles stated. The plan pursued required that the platinum should be from the same sample as used in plotting the curve. The curve was quite regular, as far as the experiments went, and it seemed feasible to extend it empirically for higher temperatures and resistances.

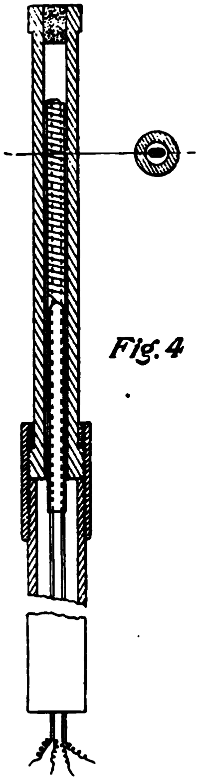


Fig. 4

The platinum, about 6 feet in length, was coiled around two clay pipe-stems and inserted in a porcelain combustion tube closed at one end, about 10 inches long and 1 inch diameter. (See Fig. 4.) The ends of the coil terminated in four heavy platinum wires, and were led out through a clay plug.

The four terminals were soldered to heavy copper wires, and insulated from each other by glass tubing. These, in turn, were protected by a wrought-iron pipe joined to the combustion tube.

To use the pyrometer it is only necessary to insert the porcelain end in the source of heat until it reaches the temperature of the furnace. Then measure the resistance and refer to the plotted curve for the temperature.

FLEXURE OF AN ELASTIC RING.

BY PROF. DE VOLSON WOOD.

A thin, uniform, circular, elastic ring hangs on a pin; required its form after distortion.

THE problem is the same as if the ring be divided by a vertical, meridian plane, and one half only be considered, the upper end being rigidly fixed, and a couple and horizontal force substituted for those acting when the ring is uncut.

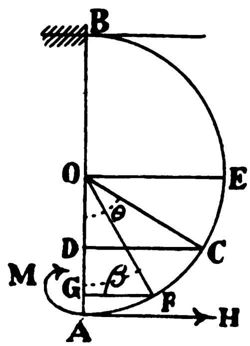


FIG. 1.

In Fig. 1 let

r, be the radius of the middle arc of the ring,
w, the weight of unity of length of the ring,
θ, the angle AOC,
β, the angle AOF, being less than θ.
s, the arc measured from A,
I, the moment of inertia of a transverse section of the ring,
E, the co-efficient of elasticity,
M, the moment of stress at any point,
M_0, the moment of the couple at A,
H, the horizontal force at A,
ρ, the radius of curvature after flexure,
φ, the change of direction of the tangent caused by distortion.

Then,

$$r d\theta = \rho\, d\varphi = ds. \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The theory of flexure gives,

$$\frac{EI}{\rho} = M, \therefore d\varphi = \frac{M}{EI} ds = \frac{Mr}{EI} d\theta, \text{ or } \frac{Mr}{EI}\, d\beta \ \ldots\ldots\ldots (2)$$

The moment of an elementary weight at F in reference to the variable origin C, will be,

$$wrd\beta\,(DC - GF),$$

and for all the weight from A to C will be

$$\int_o^\theta (\cos\theta - \cos\beta)\, d\beta = (\theta \sin\theta + \cos\theta - 1)\, wr^2 \ldots\ldots (3)$$

The entire moment at C will be

$$M = (\theta \sin\theta + \cos\theta - 1)\, wr^2 - M_o + rH\,(1 - \cos\theta) \ldots (4)$$

and this in equation (2) gives, for the change of direction at C,

$$EI\varphi = r\int_o^\theta \Big[(\theta\sin\theta + \cos\theta - 1)\, wr^2 - M_o + r\,H\,(1 - \cos\theta)\Big] d\theta.$$

$$= r\Big[\sin\theta - \theta\cos\theta + \sin\theta - \theta)\, wr^2 - (M_o - rH)\,\theta - rH\sin\theta\Big] \ldots\ldots\ldots (5)$$

But since the upper end is fixed, φ will be zero for $\theta = \pi$;

$$\therefore M_o + rH = o \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

which shows that the moment of H in reference to the centre O is equal and opposite to M_o, a result which might have been antici-

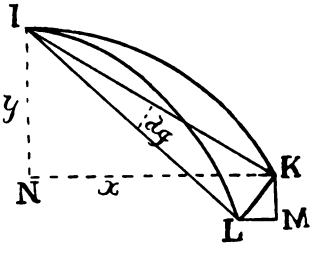


FIG. 2.

pated. Let IK, Fig. 2, be any portion of the ring, K being deflected to L by a moment at I, y the ordinate of K from I, and x the abscissa, then by means of equation (2),

$$KL = IKd\varphi = IK\,\frac{Mr}{EI}d\theta$$

$$LM = yd\varphi = \frac{Mry}{EI}d\theta = \delta_x \quad \dots\dots\dots\dots\dots\dots\dots (7)$$

$$KM = xd\varphi = \frac{Mrx}{EI}d\theta = \delta_y \quad \dots\dots\dots\dots\dots\dots\dots (8)$$

Referring to Fig. 1 we have for F in reference to C,

$$y = DG = r\,(\cos\beta - \cos\theta)$$
$$x = DC - GF = r\,(\sin\theta - \sin\beta.)$$

If there be a continuous moment from B to F we have from (3) and (7).

$$EI\delta_x = r^2\int_\beta^\pi [w\,(\theta\sin\theta + \cos\theta - 1) - (M_o - rH) - rH\cos\theta]$$

$$(\cos\beta - \cos\theta)\,d\theta = r^2\Big[-(M_o - rH)\,\pi\cos\beta + \tfrac{1}{2}\,\pi rH - wr^2$$
$$[\tfrac{3}{4}\sin\beta - \beta(1 - \tfrac{1}{2}\sin^2\beta) - \beta\cos\beta + \sin\beta + \tfrac{1}{4}(\pi - \beta)] + (M$$
$$- rH)(\beta\cos\beta - \sin\beta) + rH(\cos\beta\sin\beta - \tfrac{1}{4}\sin 2\beta - \tfrac{1}{2}\beta)\Big] \dots (9)$$

But for $\beta = o$, $\delta_x = o$;

$$\therefore\ 2rH - M_o = \tfrac{1}{4}\,wr^2 \dots\dots\dots\dots\dots\dots\dots (2)$$

which, combined with equation (6) gives,

$$H = \tfrac{1}{2}\,wr,\ M_o = \tfrac{1}{2}\,wr^2 \dots\dots\dots\dots\dots\dots (11)$$

These reduce equations (4), (5), (9), after changing β to θ in (9) so as to have the same variable in all the equations, to

$$M = wr^2\,[\theta\sin\theta + \tfrac{1}{2}\cos\theta - 1] \dots\dots\dots\dots\dots\dots\dots (12)$$
$$EI\varphi = wr^3\,[\sin\theta - \theta\cos\theta + \tfrac{1}{2}\sin\theta - \theta] \dots\dots\dots\dots (13)$$
$$EI\,\delta_x = wr^4\,[\theta\cos\theta\,(1 + \tfrac{1}{2}\cos\theta) - \sin\theta\,(1 + \cos\theta) + \tfrac{1}{2}\theta] . (14)$$

Similarly $EI\delta_y = wr^4\,[\tfrac{1}{4}(\pi^2 - \theta^2) - \cos\theta\,(1 + \cos\theta) - \theta\sin\theta$ $(1 + \tfrac{1}{2}\cos\theta)] \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (15)$

In equation (15), if $\theta = o$, then

$$\delta_y = 0.4674\,\frac{wr^4}{EI} \dots\dots\dots\dots\dots\dots (16)$$

which gives a practical formula for finding the elongation of the vertical diameter. After distortion the vertical diameter will be $2r + \delta_y$

For instance, let the metal be cast iron, $w = 0.26\ bt$ where b is the breadth and t the thickness of the ring, $E = 20{,}000{,}000$, then

$$\delta_y = 0.00000007291 \frac{r^4}{t^2} \ldots\ldots\ldots\ldots\ldots (17)$$

If $\theta = \frac{1}{2}\pi$ in (14), it gives

$$\delta_x = -0.2146 \frac{wr^4}{EI} \ldots\ldots\ldots\ldots\ldots (18)$$

which, compared with equation (16), shows that the vertical diameter elongates nearly 2.18 times as much as the horizontal diameter is shortened.

These formulæ are exact for incipient flexure, and are sufficiently so for small finite displacements. In the following example

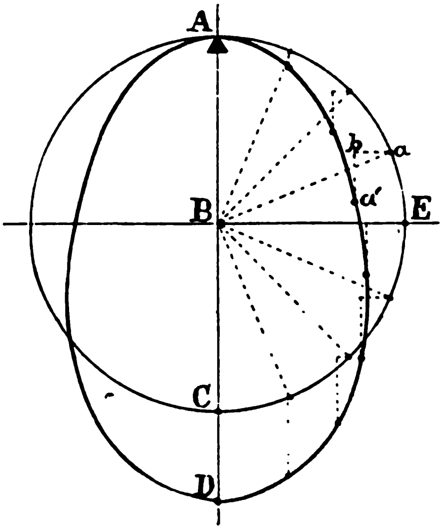


FIG. 3.

it will be assumed that they are correct for an elongation of the vertical diameter of 4.67 inches. The chief error of this assumption arises from the change of the lever arms of the weights, which in so thin a ring amounts to considerable.

Let the radius of the centre line be 10 inches, thickness 0.0125 inches, and the other dimensions as above, then equations (14) and (15) become

$$\delta x = 10 \left[\theta \cos\theta \left(1 + \tfrac{1}{2}\cos\theta\right) - \sin\theta \left(1 + \cos\theta\right) \tfrac{1}{2} + \tfrac{1}{2}\theta\right]$$

$$\delta_y = 10 \left[\tfrac{1}{4}\left(\pi^2 - \theta^2\right) - \cos\theta \left(1 + \cos\theta\right) - \theta \sin\theta \left(1 + \tfrac{1}{2}\cos\theta\right]\right.$$

These equations give the following table, by means of which Fig. 3 has been constructed to a scale of $\frac{1}{10}$th its full size.

θ	0	$\frac{1}{8}\pi$	$\frac{1}{4}\pi$	$\frac{3}{8}\pi$	$\frac{1}{2}\pi$	$\frac{5}{8}\pi$	$\frac{3}{4}\pi$	$\frac{7}{8}\pi$	π
δx	0	−0.098	−0.630	−1.510	−2.146	−1.962	−1.060	−0.207	0
δy	4.674	4.323	3 549	3.116	2 804	2.743	2.088	0.841	0

LATEST DEVELOPMENTS IN COMPRESSED AIR MOTORS FOR TRAMWAYS.*

BY PROF. D. S. JACOBUS.

COMPRESSED air motors, if economically practicable, are especially desirable for underground haulage, because they require no fuel, involve no danger of fire, and not only do not heat and foul the atmosphere by the emission of smoke and combustion gases, but do, on the contrarv, by the emission of expanding fresh air, cool and improve the atmosphere and aid ventilation.

The highest developments in the use of compressed air motors for tramways are to be found, in the opinion of the writer, in the principles of the Mekarski car motor as applied to street car locomotion, and it is thought that notes taken regarding this system, during a recent trip to Europe, where two plants are in successful operation—one at Nantes and the other at Vincennes—will be interesting to mining engineers.

The plant at Nantes operates a street line 5.2 miles long, requiring about 20 motors; the one at Vincennes has about 7 miles of road. Each car at Nantes carries its own motor; at Vincennes, however, the motor car is arranged to tow a second car containing no motor.

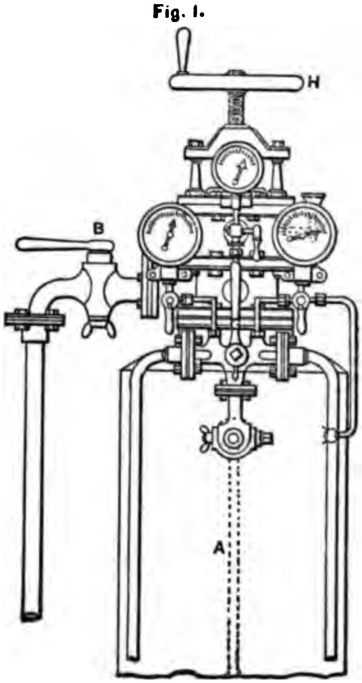
* Presented at the meeting of the American Institute of Mining Engineers, New York, September, 1890.

The road at Nantes is the older, having been in successful operation for ten years, during which time neither the American Consul, Mr. Shackelford, who has resided at Nantes for about five years, nor the Vice-Consul, Mr. Bennett, who has been at Nantes ever since the road started, has ever seen anything go wrong with the motors.

DESCRIPTION OF RAILROAD AT NANTES.

Motor Car.—Two small engines are connected so as to rotate the front axle of the car, a reversing lever being used to alter the

Fig. 1.



Regulating Mechanism of the Mekarski Motor.

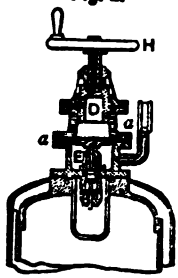
cut-off and run the motor in either direction. The compressed air is stored in ten tanks, fastened under the car ; eight of these tanks being connected together and constituting what is called the battery, and the other two forming the reserve. Air may be admitted from either the battery or the reserve to the tank A, Fig. 1, whence it passes through a mass of hot water before it reaches the regulating valve, the construction of which can best be seen in Fig. 2.

The valve is opened and closed by a difference of the air pressure acting on the two sides of the diaphragm *a a*. The pressure in the space *E* will therefore be governed by the air pressure that is brought to bear on top of the diaphragm, which pressure can be varied at will by means of the piston *D*. From the regulating valve the air passes to the three-way cock *B*, Fig. 1, which causes it to pass either to the engines or to the air-brakes. The dimensions are as follows:

Diameter of cylinders of engines, $5\frac{5}{16}$ inches.
Stroke of cylinders of engines, $10\frac{1}{4}$ inches.
Compressed air cylinders, about 18 inches diameter and 5 feet long.

The cylinders containing compressed air are not all of the same size. The total capacity of the sets of connected cylinders, as given in Mekarski's circular, is such that each kilogram of pressure

Fig. 2.



REGULATING VALVE.

per square centimetre corresponds to 2.5 kilograms weight of air in the battery and .8 kilograms of air in the reserve. The pressure of air employed at Nantes when the motors are fully charged is 30 kilograms per square centimetre in both the battery and the reserve.

The motors run very steadily, there being no appreciable teetering or rocking when the car is at full speed. In starting there is no jerking motion experienced, and, as air brakes are used for stopping, the quickness with which this is done may be varied at will. The air exhausted from the motors makes a slight noise, but not enough to cause any annoyance to persons residing near the car lines.

AIR COMPRESSORS AND STORAGE TANKS.

The air compressors are of the compound type in which air is first compressed into an intermediate receiver and from this enters

the high pressure cylinder, where it is compressed to the final pressure. The air cylinder pistons are both fastened to the same rod. The cylinders are single acting, the pressure in the receiver being made to act constantly on one side of the high-pressure piston. The steam cylinder is set parallel to the air cylinders, and the pistons of all the cylinders are connected to the same fly-wheel shaft.

The dimensions are about as follows :

	Four compressors at main station.	Two compressors at supplementary station.
	Inches.	Inches.
Length of stroke of air cylinders	23.6	17
Length of stroke of steam cylinder	39.4	28
Diameter of high pressure air cylinder	9.4	7
Diameter of low pressure air cylinder	19.7	15
Diameter of steam cylinder	19.7	14

The compressors are made to force air into a receiving tank until the arrival of a motor to be charged. The motor is first connected to the receiving tank, and when its cylinders become charged to the pressure of the tank, they are connected directly to the compressor until the required pressure is reached, at which point there is an automatic valve that acts and prevents an excess, in case the person charging the motor does his work in a careless manner. The receiver is always at a lower pressure than that required for the cylinders of the car, so that all the work of storing the air is not done against the maximum pressure. At the same time that the air tanks are being charged, the water in the tank A, Fig. 1, is heated by passing steam into it. The quantity of water lost by vaporizing during the trip is just about equal to that resulting from the condensation of the steam required to be used in heating the water, so that there is no escape of steam or hot water at the charging station. No opportunity was offered to measure the temperature of this water, but, according to Mr. Mekarski, it is 160° Cent. when the motor starts from the station, and about 100° Cent. when it returns.

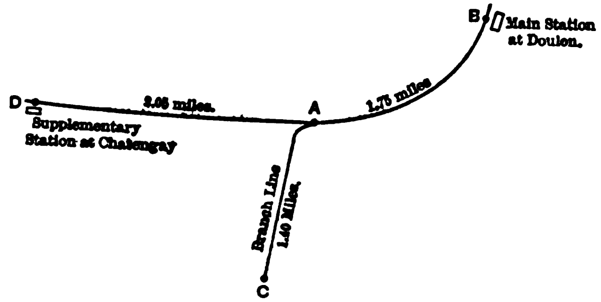
METHOD OF RUNNING THE MOTORS.

The reversing lever is first thrown forward to the last notch from the centre, the hand-wheel H is then slowly turned so that it forces the piston D, Fig. 2, downward and opens the valve admit-

ting air to the chamber E, from which it passes through the cock B, Fig. 1, to the engine. The lever is held in the forward position until the motor begins to start, and then it is brought to the notch nearest to the centre. When the lever is forward, in the last notch, the cut-off occurs at $\frac{3}{4}$-stroke, in the notch nearest the centre the cut-off is $\frac{1}{4}$.

About 6 to 10 kilograms per square centimetre are used on the engines at starting, and this pressure is preserved until the motor attains a speed a trifle faster than the average. The pressure is then shut off from the engines, provided the track is quite level, and the reversing lever thrown forward, after which the car runs a short time by its inertia. When the speed diminishes the lever is brought back to the first notch, and 6 to 10 kilograms again brought on the engines. By working the air in this way it can be used more efficiently than if a constant low throttled pressure were used. In going up grades the pressure is constantly on the engines, and, if possible, the lever in the first notch. There was no grade at Nantes so steep that this could not be done. To stop the car, the handle of the three-way cock *B*, Fig. 1, is turned, and the required amount of air pressure brought to bear on the brakes by screwing down the hand-wheel *A*. When the pressure of the air in the battery becomes too low to start quickly, or to drive the motor up a grade, the three-way cock shown at *G*, Fig. 1, is turned so as to allow the pressure of air from the reserve to be communicated to the interior of the tank *A*; the cock is then turned back to its former position,

Fig. 3.



PLAN OF ROUTE AT NANTES.

so that there will still be a high pressure of air in the reserve to be used again in case of need.

STATIONARY PLANT.

Figure 3 will give a general idea of the plan of the tracks at Nantes, although there are many more curves in the lines than are here represented.

The motors start from the main station *B*, charged to about 30 kilograms per square centimetre in both the battery and reserve, go to *A*, then to *C* and back to *A*, and finally to *D*. At the supplementary station *D* the tanks are re-charged to about 20 kilograms per square centimetre and the motor returns to *A* and then to *B*.

There are several stations along each route at which inspectors enter the cars to see if all the passengers have purchased tickets from the conductor who rides on the car.

The track is quite level, the heaviest grade being where the road crosses bridges, the roadbeds of which are higher in the middle than at the two ends. The maximum grade is 1 to .045. The grades are all short ones.

There are four compressors at the main station at Doulon and two at Chatengay, the dimensions of which have already been given. Two of the compressors at Doulon are run on Sundays and fête days, at which time there are 20 motors in use, whereas on week days one, and only for a part of the time two compressors are run, and 16 motors are in use. At Chatengay both of the compressors run on Sundays and only one during the week. The motor cars seat 16 persons without crowding and 18 with slight crowding; the back platforms are quite large, however, so that sometimes 30 or more passengers are carried at one time. There are 22 motors in all belonging to the company.

RECORD AT NANTES FOR YEAR ENDING JULY, 1889, AS GIVEN BY MR. MEKARSKI.

Fuel, 1,300 tons, at $5 per ton, delivered to station......	$6,500
Oil and waste for rolling stock, at $80 per ton...........	862
Oil and waste for stationary plant, at $80 per ton.......	300
Total number of men employed at Doulon station..... ..	7
Total number of men employed at Chatengay station....	5
Number of trips made by each motor per day...........	6
Length of each trip (one complete and one ⅔ charge of air for each trip).....................................	10.4 miles.
Number of miles made by each motor per day..........	62.4
Number of motors in use on week days.................	16
Number of motors in use on Sundays and fête days......	20
Time the first motor starts out of the station...	7 A. M.
Time the last motor starts out of the station............	7:08 P. M.
Total number of miles run during the year..............	346,000

The cost of repairs for this particular year could not be obtained, but in a statement of expenses for the year 1888 Mr. Mekarski

gives the cost of maintenance of rolling stock as 26,011 francs, or about $5,200, and of the stationary plant 15,803 francs, or $3,200.

Tests of Speed.—Table A gives the trip records taken at Nantes, and shows the average and total results deduced therefrom. It clearly exhibits the following points:

First.—The motors started with about the same rapidity as an ordinary street car—*i. e.*, they attained full speed in 12 to 16 seconds, and could be started quicker than this with an additional supply of compressed air.

Second.—The total distance run over to measure the speed was 22.55 miles and the number of stops made 61. The rate of speed, including stops, was 7.58 miles per hour, and, excluding stops, 8.52 miles per hour.

Third.—The greatest distance run with a single charge of air was 6.6 miles; this required 30 kilograms per square centimetre. In returning from the supplementary to the main station the motors ran a distance of 3.8 miles, being charged at the start to about 18 kilograms per square centimetre.

In Table A the record of the number of passengers on the car on starting up after making a stop does not include the driver and conductor. The average number of passengers is obtained by taking the average of the number on the car at each minute of the time required to make the trip.

HORSE-POWER AND COAL CONSUMPTION OF COMPRESSORS.

The mean effective pressure for 60 revolutions per minute, as shown by indicator cards taken by Mr. Mekarski, is 32 pounds per square inch. We also have

Diameter of cylinder = .5 metres = 19.7-inches; stroke = 1 meter = 3.28 feet.

$$\text{Hence, H. P.} = \frac{305 \times 32 \times 3.28 \times 60 \times 2}{33{,}000} = \text{about } 115.$$

Sixty revolutions per minute, as given above, is, in the judgment of the writer, about the average speed that would be obtained by adding together the revolutions made by the two compressors during a day, and dividing by the number of minutes, for the compressors run ordinarily at about 45 turns, and one runs all day, and the other only occasionally.

The compressor in the supplementary station compresses to only about two-thirds the pressure obtained in the compressor at the

main station, so that, to fill a given volume, its horse-power would be about two-thirds of 115, or, say 75, provided the indicator cards of the air cylinder have the same mean effective pressure. As, however, the indicator cards will be smaller, we will say that about 60 horse-power is required at this station, making the total requisite horse-power at both stations, 175.

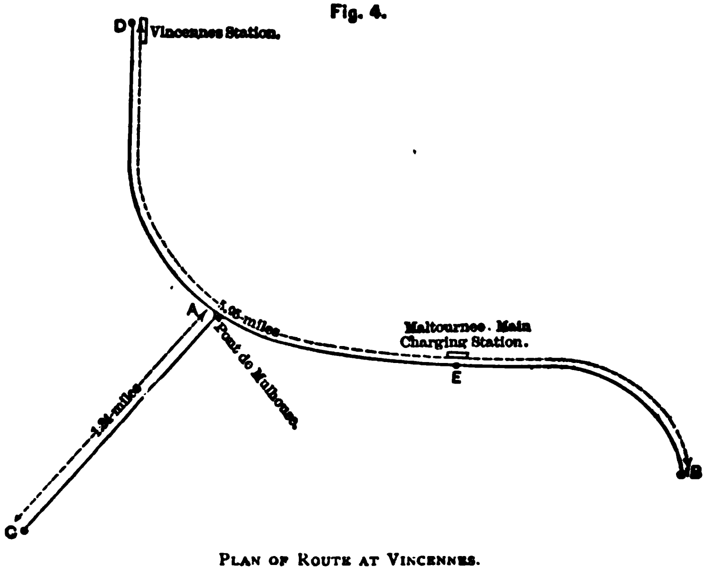
As the engines have a condenser, we will assume 3 pounds of coal per horse-power per hour, and obtain:

Coal per hour $= 175 \times 3 = 525$ pounds.
Coal per day of 12 hours $= 6{,}300$ pounds.
Figure given by Mr. Mekarski $= 1{,}300$ tons per year
$= 7{,}100$ pounds per day.

RAILROAD FROM VINCENNES TO NOGENT.

Figure 4, in which many curves have been omitted, will give an idea of the route, the distances being taken from Mr. Mekarski's pamphlet describing his system.

Fig. 4.



PLAN OF ROUTE AT VINCENNES.

The motors on this line are larger than at Nantes and are charged to a higher air pressure. The motors on the main line, *D A E B*, draw a supplementary car; they are charged at *D*, and run to *E* where they are replaced by another motor which has been

charged at *E*; from *E* the second motor and car either proceed to *B* and return to *E* without a further charge at *B*, or go back to *D* without going to *B*.

The motors that run on the branch road do not draw a supplementary car; they are charged at *E*, run to *A* then to *C* and return to *E*, making the complete trip with a single charge of compressed air. There are seats on the top and in the interior of both the motors and the cars. The number of passengers given in the record is only approximate, as it was not possible for one person to keep an exact tally for both the motor and car. Upon some sections of the route the motor and car carried as many passengers as they could accommodate.

The principal results obtained are:

First.—The motor drawing a car started in from twenty to forty seconds, or about twice the time for an ordinary street car.

Second.—The total distance over which a record was kept to determine the speed of a motor drawing a car was 11.9 miles. The average speed, including stops, was 8.58 miles per hour, and excluding stops, 9.26 miles per hour.

Third.—The motor alone ran on the branch line at 8.81 miles per hour, including stops, and at 10.65 miles per hour, excluding stops.

Fourth.—The average distance run by a motor drawing a supplementary car with a single charge of air was 3.97 miles, and this required the air in the tanks to be compressed to about 40 kilograms per square centimetre.

The details of the results observed at Nogent are given in Table B.

TIME REQUIRED TO CHARGE MOTORS.

The only case in which this is required to be done quickly, on the lines herein described, is at Vincennes Station of the Nogent Railroad. At this station the motor is disconnected from the car, run to the charging station, about 75 yards distant from the main track, charged there, and then run back to be re-connected to the same car. The motor was disconnected from the car, turned at right angles to the track by means of a turn-table, and run to the charging station, all in three minutes. The air and steam were turned on three quarters of a minute after the motor came to rest on the platform, and exactly three minutes afterward the motor was

disconnected and started back toward the turn-table. At Nantes the motors remain on the charging platforms about 15 minutes, during which time the driver oils up the engines.

ESTIMATED COST IN THE UNITED STATES.

As a basis for estimating the cost of equipping and operating a line in this country we will take a double-track road three and one-half miles in length—*i. e.*, seven miles of track, two terminal charging stations and cars starting from each station every four minutes, for twelve hours a day. One gang of men is to be employed at each station.

Two charging stations are required, one on each end of the line, unless the track is quite level and is kept *perfectly clean.* In a city where wagons are continually crossing the tracks, thereby causing the motors to be slowed down and started up very often, and in which the streets are not kept clean, much more power would be required to operate the motors than at Nantes, where there was little interference to the continuous running of the motors, except for taking on or letting off passengers, and where the rails were kept as clean as possible by a couple of track-walkers employed for the purpose. Besides this, in many cities snow could not, on some days, be entirely removed from the rails. Many more stops would have to be made for passengers in one of our larger cities than are made at Nantes. It also appears that this short run conforms with the practice adopted at Vincennes, near Paris, where the motor and car attached travel, with one charge of air, an average of 3.97 miles.

The cost of coal per mile per motor, at Nantes, at $5.00 per ton is 1.875 cents, or at $3.50 per ton 1.31 cents. Assuming that the motors as run in this country require one and a-half times the power of that those do at Nantes, the coal per mile per motor will be 1.96 cents.

The total number of miles made by the motors per day on the proposed plant is $\frac{60}{4} \times 12 \times (3\frac{1}{2} \times 2) = 1260$, and the cost of coal per day about 1260×1.96 cents = $24.50.

The waste and oil for rolling stock, at $80.00 per ton, at Nantes, or about 30 cents per gallon, is 0.25 cents per mile per motor or $3.15 per day. If oil is 50 cents per gallon this becomes about

\$5.25 per day.* The oil for the stationary plant at this same price is about \$1.75 per day.

The cost of maintenance of the rolling stock as given in the printed list by Mr. Mekarski is .052 francs per kilometre or 1.67 cents per mile per motor. Assuming that the greater price paid for labor in the United States will add 50 per cent. to this figure, we have for the repairs per mile, per motor, $1.67 \times \frac{3}{2} = 2.5$ cents, or \$31.50 for the entire number of motors per day.†

The cost of maintenance of the stationary plant obtained in a similar way is \$19.50 per day.

The number of men that would be required at each station, exclusive of those to make repairs, are: One engineer, one oilman, two firemen, two workmen, two charging men and an extra engineer who would take the place of either of the other two in case of sickness. These figures correspond with what Mr. Mekarski gave me for the main station at Nantes.

The items for supplies and repairs are therefore:

Cost of coal per day, at \$3.50 per ton	\$24.50
Oil and waste for rolling stock	5.25
Oil for stationary plant	1.75
Maintenance of rolling stock	31.50
Maintenance of stationary plant	19.50
Cost per day, total	\$82.50

The items for labor are:

3 engineers,	at \$3.00	per day	\$9.00
2 oilmen,	" 2.00	"	4.00
4 firemen,	" 2.50	"	10.00
4 workmen,	" 1.75	"	7.00
4 charging-men,	2.00	"	8.00
Total expended in labor per day			\$38.00

ESTIMATE, INCLUDING INTEREST AND DEPRECIATION ON PLANT.

We will assume that the cost of the two buildings required for this plant to be the same as the single larger one that would be required if horses were used; then we have the depreciation of the machinery

* This assumes that the price of waste in the United States is 66 per cent. higher than at Nantes.

† Although it was fully appreciated that this figure is one of the most important in an estimate of this kind, it has been impossible to check it by directly observing the number of men in the repair-shop, because all repairs are made in Mr. Mekarski's shop at Doulon, and this shop is usually employed on other commercial work. There are 22 motors in all belonging to the company, and it is said that 20 of these have been run every Sunday and fête day since the road was started, so that it appears to be exceptional to have more than two motors undergoing repairs at the same time.

and motors in Mr. Mekarski's system to balance against the replacement and acclimating of horses, in a system in which horses are the motive power. The approximate cost of the machinery will be:

4 compressors..............................	$15,000
4 boilers..............................	5,000
22 motors..............................	25,000
Total..............................	$45,000

Taking interest and depreciation at 10 per cent., we have $4,500 per year, or about $12.50 per day.

The total cost per day of the plant, neglecting the wages of conductors and drivers, cost of repairs and interest on buildings and portions of the motors equivalent to an ordinary street car, will be:

Fuel, oil and repairs..............................	$82.50
Labor..............................	38.00
Interest and depreciation of machinery..............................	12.50
Total..............................	$133.00

In the case above considered, the men work on very long shifts—say 13 hours per day. Ordinarily, if there is enough traffic to require the cars to be run at four minute intervals during the busy part of the day, they will have to be kept running in the evening and make the number of working hours per day 18 instead of 12.

If the trips are so arranged that the same number of miles is made by the motors in a day of 18 hours as in one of 12—the motors running more frequently during the busy part of the day than in the evening and early morning—the cost per day with two gangs of men at each station, will be $38.00 × 2 = $76.00 for labor, and this plus $95.00 for fuel, etc., gives $171.00 as the total expense, apart from other items which would be common to roads operated either by compressed air or by horses.

COMPARISON WITH HORSE TRACTION.

The following estimate of the cost, if horse traction is employed, has been presented to the writer for a plant running cars over a 3½-mile double track at four minute intervals, for 12 hours a day:

Cost of feeding 350 horses per day..............................	$105.00
Twenty stablemen at $1.75 per day..............................	35.00
One stable foreman..............................	2.50
One stable doctor..............................	3.00
Four hitchers at $1.50 per day..............................	6.00
Medicines..............................	2.00
Replacement of horses and acclimating..............................	37.50
Shoeing..............................	14.00
Total..............................	$205.00

In order to compare these figures with the results obtained for the Mekarski Motors we must add to the total sum the interest on the capital invested in horses and the cost of repairs made on cars. Assuming each horse to be worth \$100, we have for the total value of the horses $350 \times \$100 = \$35,000$, and 5 per cent. on this is \$1,750, or about \$5 per day, making the total per day, if the cost of repairs made on the cars is neglected, $205 + 5 = \$210$.

The following are, therefore, the results obtained:

COST PER DAY.

Neglecting wages of conductors and drivers, cost of repairs and interest on buildings:

Mekarski Compressed Air Motor Cars,	For day of 12 hours	\$133
	For day of 18 hours	\$171
Horse traction, for day of 12 hours, not including repairs made on cars		\$210

It must, however, be borne in mind that the figures given in the estimate for repairs of the Mekarski Motors are for a plant that has been in operation a long time and in all probability brought to its best condition in regard to attendance. If a new plant were started in the United States, inexperienced men would have to be put in charge of the motors, and in all probability the repairs for the first year of the running would far exceed the figures above given; the higher wages the men running the motors would have to be paid, as compared with ordinary drivers, is also not taken into consideration. Again, men not used to running the motors would use the air with less economy than they do now at Nantes, and probably the addition of 50 per cent. to the cost per mile, for the coal burned, on account of dirty tracks, etc., will not be a sufficient margin. It is also probable that the pressure of air stored in the tanks will have to be made very much higher than is actually required to make the trip, so that an extra amount of air can be drawn on in case of an emergency, and as this was not done at Nantes, at which place the reserve had to be thrown in toward the end of nearly every trip, an extra allowance should be made on this account. Taking all this into consideration, it may be that the coal consumed per motor per mile in the United States will be twice, or even three times, that at Nantes.

The greatest drawback to the Mekarski Motor, however, is to be anticipated when snow cannot be kept from the rails, for as each motor has only a definite charge of air, it may be exhausted in contending with the snow, and will then come to a standstill on the track.

TABLE A.—*Record of Speed of Mekarski Air Motors at Nantes.*

Station at which the Motor was Charged with Compressed Air.	Section of the Line run over.	Time.		Duration of Stop in Seconds.	Time Required to Start in Seconds.	Condition of Track.	Number of Passengers.	Pressure of Air in Tanks. kilos. per sq. cent.		REMARKS.
		Of Starting from and Arriving at Main Stations.	That intermediate stops were made, and time other data was observed.					Battery.	Reserve.	
		A. M.								
D	A to B	10.17					25	10	19	Started from the Central Station A.
			$10.17\frac{1}{2}$	30	20		26			
			10.20	15	15	Level	27			
			$10.21\frac{1}{2}$	10			28			
			10.23	15	15	Level	27			
			10.24	75			20	6	19	
			10.27	20	13	Slight down grade	14			
			10.28	10			14			
			$10.29\frac{1}{2}$	5			13			
			10.30				12			
			10.31	10			10			
		10.32					10	$3\frac{3}{4}$	19	Arrived at the main Charging Station B.
		A. M.								
B	B to A	$10.37\frac{1}{4}$			12	Level	2	$29\frac{3}{8}$	$29\frac{1}{2}$	Started on another motor, fully charged with compressed air. Used air from the Reserve until $10.39\frac{1}{4}$, and then started to use from the Battery.
			$10.39\frac{1}{4}$				2		$26\frac{1}{2}$	
			10.41				2	28	$26\frac{1}{2}$	
			$10.44\frac{1}{4}$	50			14			
			$10.44\frac{1}{2}$	5			15			
			10.49	10			16			
		$10.49\frac{1}{2}$					16	$24\frac{1}{4}$	$26\frac{1}{2}$	Arrived at Station A.

B	A to C	A. M. 10.52½	......	......	.....	....	10	24¼	26½	Continued run on same car.
			10.57½	50	12	Level	10	24¼	26½	
			11.00	60	.....	....	10	......	......	On Switch.
			11.02	10	.....	....	9	......	......	
		11.04	......	......	.....	....	9	17⅝	26½	Arrived at Station C.
B	C to A	A. M. 11.14½	......	......	.....	....	8	17⅝	26½	Continued run on same car.
			11.16¼	90	17	Up slight grade...	8	14½	26½	On switch waiting for other car. Pressure on engines at starting 4½ kilos. per sq. cent.
			11.21½	20	15	On sharp curve..	8	......	......	Pressure on engines at starting 11 kilos. per sq. cent.
		11.26¼	......	......	.....	....	8	12	26½	Arrived at Station A.
B	A to D	A. M. 11.27½	......	......	.....	....	8	12	26½	Continued run on same car.
			11.29	15	13	Level.......	10	......	......	Pressure on engines at starting 8 kilos. per sq. cent.
			11.31½	5	17	Up slight grade...	7	......	......	
			11.33½	20	15	Level............	7	8	......	
			11.35½	10	.....	....	4	......	......	
			11.36½	5	.....	....	5	......	......	
			11.38	10	20	Up slight grade and on curve....	4	6½	26½	
			11.41	......	.....	....	4	......	......	Slowed up on switch.
			11.41½	......	.....	....	4	......	......	Reserve thrown in for a short time on a level track.
		11.43	......	......	.....	....	4	5	22	Arrived at Station D. Motor remains at this station to be recharged.

TABLE A.—*Continued.*

Station at which the Motor was Charged with Compressed Air.	Section of the Line run over.	Time. Of Starting from and Arriving at Main Stations.	Time. That Intermediate Stops were made and time other data was observed.	Duration of Stop in Seconds	Time required to Start in Seconds.	Condition of Track.	Number of Passengers.	Pressure of Air in Tanks, kilos. per sq. cent. Battery.	Pressure of Air in Tanks, kilos. per sq. cent. Reserve.	REMARKS.
D	D to A	A. M. $11.47\frac{1}{2}$	......	......	15	......	5	$17\frac{1}{2}$	21	Started on another motor charged at D to two-thirds its capacity.
			$11.51\frac{1}{2}$	5	15	Level curve......	5	......	......	
			$11.51\frac{3}{4}$	5	......	......	6	......	......	
			11.53	15	......	......	12	......	......	
			11.57	15	......	......	12	14	21	
			12.00	10	12	Level......	13	......	......	
			12.02	......	......	......	12	$12\frac{1}{2}$	......	
			12.03	10	......	......	12	......	......	
		$12.04\frac{1}{4}$	......	......	......	......	12	$11\frac{3}{4}$	21	Arrived at Station A.
D	A to B	P. M. 12.07	......	......	......	......	12	$11\frac{3}{4}$	21	Continued run on same motor.
			$12.08\frac{1}{2}$	......	......	......	13	......	......	
			12 10	5	......	......	13	......	......	
			12.13	30	......	......	9	......	......	
			$12.16\frac{1}{2}$	......	......	......	9	7	21	
			$12.18\frac{1}{2}$	10	......	......	5	......	......	
		12.19	......	......	......	......	5	6	21	Arrived at the main charging station at B, where the motor is re-charged.

	B to A	P. M. 12.28½			17	Level.	9	30	27	Started on another motor fully charged at main Charging Station B.
			12.31	10			10			
			12.31¼	5			11	26½	27	
			12.35	40			5			
			12.37½	5			6			
			12.38¼	10			7			
			12.39				6			
			12.40	*240	10	Level.	5			Delayed on Switch.
		12.45½					5	22½	27	Arrived at Station A.
B	A to C	P. M. 12.47					28	22½	27	Started from Station A.
			12.48½	5			29			
			12.51½				29	20½	27	
			12.55½	15			27			
			12.57	10			26			
		12.59½					26	15½	27	Arrived at Station C.
B	C to A	P. M. 1.07½					5	15½	27	Started from Station C.
			1.13	30			8			
			1.16	5			8	11	27	
		1.18½					8	10	27	Arrived at Station A.
B	A to D	P. M. 1.20½					9	10	27	Started from Station A.
			1.20½	10			12			
			1.24				15			Slowed down for a short time to wait for cart to be removed from the track.
			1.25½				16			
			1.27	30	15	Level.	14	7	24½	Reserve used at starting.
			1.30	20			10		22½	" " " "
			1.32	45	18	Level.	3	6	18½	" " " "
			1.35				3			Reserve used on level track.
		1.38					3	4½	16½	" " " " "

* This delay is not included in the time expended in intermediate stops.

TABLE A.—*Continued.*

Station at which the Motor was Charged with Compressed Air.	Section of the Line run over.	Time. Of Starting from and Arriving at Main Stations.	Time. That intermediate stops were made and time other data was observed.	Duration of Stop in Seconds.	Time required to Start in Seconds.	Condition of Track.	Number of Passengers.	Pressure of Air in Tanks, kilos. per sq. cent. Battery.	Pressure of Air in Tanks, kilos. per sq. cent. Reserve.	REMARKS.
D	D to A	P. M. 1.39½					3	18	20	Started on another motor charged to two-thirds its capacity at the Supplementary Station at D.
			1.42½	10	20	Level	7			
			1.46	25			16			
			1.47½	30	20	Level	18			Only four kilos. per sq. cent. on engines at time of starting.
			1.49	25			21	15	20	
			1.51	45	20	Level	30			
			1.54	10	22	"	29			Only six kilos. per sq. cent. on engines at starting.
			1.56	10	18	"	27			
		1.56½					27	11¾	20	Arrived at A. Nearly all of the passengers left the car, for which reason the record was not continued.
D	A to B	P. M. 4.53					18	12¼	21⅛	Took another car at A.
			4.53½	20			21			
			4.56	5	12	Level	23			
			4.56¾	5			22			
			4.59	10			22			
			4.59½	50	10	Level	16	9¼	21⅛	Nine kilos. per sq. cent. on engines at starting.
			5.03	10	15	"	14			Five kilos. per sq. cent. on engines at starting.
		5.06					14	8	21⅛	

Totals and Averages of the Record Given in Table A.—Railroad at Nantes.

		Per Single Trip.							Per Single Charge of Air.				
					Time Required to Make Trip.		Miles per Hour					Miles per Hour.	
Station at which the Motor was Charged with Compressed Air.	Section of the Line run over.	Average Number of Passengers.	Total Number of Intermediate Stops.	Distance Traveled in Miles.	Including Intermediate Stops.	Excluding Intermediate Stops.	Including Intermediate Stops.	Excluding Intermediate Stops.	Average Number of Passengers per Trip.	Total Number of Intermediate Stops.	Distance Traveled in Miles.	Including Intermediate Stops.	Excluding Intermediate Stops.
D	A to B	20	10	1.75	15 min.	11 m. 50 s.	7.0	8.9	......	......	......	......	......
B	B to A	8	3	1.75	12 m. 15 s.	11 m. 10 s.	8.6	9.4	......	......	......	......	......
B	A to C	9.8	3	1.40	11 m. 30 s.	9 m. 30 s.	7.3	8.8	......	......	......	......	......
B	C to A	8	2	1.40	11 m. 45 s.	9 m. 55 s.	7.1	8.5	......	......	......	......	......
B	A to D	6.1	6	2.05	15 m. 30 s.	14 m. 25 s.	7.9	8.5	8.0	14	6.6	7.76	8.80
D	D to A	9.8	6	2.05	16 m. 45 s.	15 m. 45 s.	7.3	7.8	......	......	......	......	......
D	A to B	10.4	3	1.75	12 m.	11 m. 15 s.	8.7	9.3	10.1	9	3.8	7.93	8.44
B	B to A	7.8	6	1.75	13 m.	11 m. 50 s.	8.1	8.9	......	......	......	......	......
B	A to C	28	3	1.40	12 m. 30 s.	12 m.	6.7	7.0	......	......	......	......	......
B	C to A	6.5	2	1.40	11 m.	10 m. 25 s.	7.6	8.1	......	......	......	......	......
B	A to D	9.2	4	2.05	17 m. 45 s.	16 m.	6.9	7.7	12.9	15	6.6	7.30	7.88
D	D to A	16.7	7	2.05	17 m.	14 m. 25 s.	7.2	8.5	......	......	......	......	......
D	A to B	18.1	6	1.75	13 m.	11 m. 20 s.	8.1	9.3	17.4	13	3.8	7.60	8.85
Totals for all runs........		158.4	*61	22.55	179 m.	159 m. 50 s.	98.5	110.7					
Average.......		12.2	......	......	....	....	7.58	8.52					

* Number of stops, including those at main stations, 74.

TABLE B.—*Record of Speed of Mekarski Air Motors, at Vincennes and Nogent, near Paris.*

The Motors draw a car on the Main Line and run alone on the Branch Line.

Station at which the Motor was Charged.	Section run over.	Time. Of Starting from and Arriving at Main Stations.	Time. That intermediate stops were made and other data was observed.	Duration of Stop in Seconds.	Time required to Start to the maximum speed in Seconds.	Condition of the Track.	Number of Passengers Approximate.	Pressure of Air in Tanks, kilos. per sq. cent. Reserve.	Pressure of Air in Tanks, kilos. per sq. cent. Battery.	REMARKS.
D	D to A	P. M. 12.03¼	....	.....	......	....	80	44	36½	Motor drawing a car, starting from Station D.
			12.09	30	30	Up slight grade.....	80	......	.....	
			12.12	10	40	Up slight grade.....	80	43	21	Eight kilos. per sq. cent. on engines at starting. Reversing lever last notch from centre for 20 seconds, and on 1st notch afterward.
			12.13	*240	......	Heavy grade.......	100	......	.....	Reserve used. Went up the hill slowly 16 kilos. per sq. cent. on engines.
			12.15	......	......	" "	.....	......	.....	
			12.22	20	25	Slight down grade..	100	... ..	.....	Reversing lever in second notch from centre.
			12.25	10	20	Slight down grade..	100	......	.....	
			12.26	20	25	Down grade	100	......	.....	Only 3 kilos. per sq. cent. on engines at starting.
			12.28	. ....	......	Heavy down grade..	100	......	.....	Longest hill. Five kilos. per sq. cent. constantly on brakes.
		12.29½	....	.....	.....	....	100	29	13½	Arrived at Station A.

*** This delay is not included in the time expended in intermediate stops.**

D	A to E	P. M. 12.31½					45	29	13½	Continued run on same motor.
			12.35	25	30	Slight up grade	44			Six kilos. per sq. cent. on engines at starting.
			12.37				44			
			12.38	15	30	Slight up grade	40			
			12.41	10	45	Slight up grade	40			
		12.41½					40	25½	7¼	Arrived at E. Motor disconnected from car and ran into station to be charged,
E	E to B	P. M. 1.12½					75	39	29½	Started on another motor drawing a car.
			1.17	55	20	Level	75			Eleven kilos. per sq. cent. on engines at starting. Reversing lever in last notch from centre 10 seconds, and in first, 10 seconds.
			1.18	5	20	Down grade	70			
			1.21			Up grade and on a curve.	70			Ten kilos. per sq. cent. on engines. Reversing lever in first notch from centre.
		1.23					70	39	14	Arrived at B.
E	B to E	P. M. 1.28½					10	39	14	Returned from B.
			1.30	10			12			
			1.32	10	25	Slight up grade	15			
			1.33	10			20			
			1.33½	5	20	Slight up grade.	20			Reserve thrown in.
			1.36	25			25			
			1.37				25	33	6	
		1.39½					25	29¼	5	Arrived at E. Motor disconnected from car and ran into the station to be charged.

TABLE B.—*Continued.*

Station at which the Motor was Charged.	Section run over.	Time. Of Starting from and Arriving at Main Stations.	Time. That intermediate stops were made and other data was observed.	Duration of Stop in Seconds.	Time required to Start to the maximum speed in Seconds.	Condition of the Track.	Number of Passengers Approximate.	Pressure of Air in Tanks, kilos. per sq. cent. Reserve.	Pressure of Air in Tanks, kilos. per sq. cent. Battery.	REMARKS.
E	E to A	P. M. 1.44½	....	.....	.....	....	40	43	41¼	Took another motor drawing a car. The driver of the motor started at first using air from the reserve and afterward changed over to the battery.
			1.47	5	20	....	42	......	......	Going up hill. Ten kilos, on engine.
			1.48	......	......	....	......	......	......	Lever in second notch from centre.
			1.50	......	......	....	42	39	32	
			1.51	35	......	....	50	.....	.....	
		1.55	....	.....	......	....	50	39	27	This motor went on to Vincennes.
E	C to A	P. M. 2.37½	....	...	......	Down hill..........	45	41	32	Started on a motor that came from E without drawing a car, did not draw car on branch line.
			2.40	10	......	Down hill..........	44	......	......	
			2.42	40	.....	Slight down grade	42	......	......	
			2.43	15	.....	Level............	41	......	.....	
			2.45	45	......	....	40	......	......	
		2.46½	....	.....	......	....	40	40⅜	26½	Arrived at C.

		P. M.								
E	C to A	3.15¾			15	Level	21	40¾	26½	Returned on same motor to A.
			3.17	35			36			
			3.18	15			36			
			3.20	10			37			
			3.21	20			38			
		3.25					38	36	15	Arrived at A. Motor returned to E.
E	A to D	3.37½				Up longest hill	70	41	25	Motor drawing a car. When grade was reached an air pressure of 16 kilos. per sq. cent. was used on the engine, and the lever was at the second notch.
			3.39½			Up longest hill	70			Fourteen kilos. on engine. Reversing lever in second notch. Motor going about as fast as a horse that is slowly walking, or about as fast as horses will pull a car up a very steep grade.
			3.40			Up longest hill	70			
			3.41	20	25	Slight up grade	70			Nearly to the top of the grade when this stop was made. It required 8 kilos. per sq. cent. on the brakes to hold the train from starting backward down the hill.
			3.42	10		Down grade	75			
			3.45½			Short up grade	75	37	8	
			3.46			Down grade	75			
			3.48	150*			70	38	8	
			3.53	40	30	Level	65			
		3.59					65	33¾	6¼	

* This delay is not included in the time expended in intermediate stops.

Totals and Averages of the Record given in Table B.

Railroad at Vincennes and Nogent, near Paris.

	Motor Drawing a Car on the Main Line D A E B.	Motor Alone on the Branch Line A B.
Total distance run during round trip, in miles	11.9	2.68*
Total number of stops made	22	8
Number of times that the motor is charged to make round trip	3	1
Average number of passengers, approximate	59	38
Time to make run, including all stops except at the main stations, and two delays mentioned in the table	83 m. 15 s.	18 m. 15 s.
Time excluding all stops	77 m. 5 s.	15 m. 5 s.
Miles traveled per hour, including stops	8.58	8.81
Miles traveled per hour, excluding stops	9.26	10 65

* This single motor runs, in addition to this length of 2.68 miles, the double distance of A from E, which distance I do not know, but should judge it to be about 1½ miles, so that the total distance that the motor runs without re-charging is about 2.68 + (2 × 1½) = 5.68 miles.

QUICK METHODS OF PERFORMING SOME NUMERICAL OPERATIONS.

BY PROF. H. A. WOOD, OF THE STEVENS SCHOOL.

Addition and Subtraction Combined.

A LITTLE practice on the following method will enable an accountant to add two sets of several numbers each, and take their difference, without making partial additions, with nearly the facility of merely adding the separate columns. We will first explain an example in which no carrying is required.

(1) It is required to find the difference between the sum of the numbers embraced by A and B without making partial additions.

$$\begin{array}{r}
\left.\begin{array}{r} 44859 \\ 33478 \\ 7832 \\ 29473 \end{array}\right\} A \\
\hline
\left.\begin{array}{r} 24785 \\ 4937 \\ 6849 \end{array}\right\} B \\
\hline
79071 \quad
\end{array}$$

In this case we simply subtract, in each case, the sum of the numbers in column B from the next higher number of tens, and add the difference to column A. (1) The sum of 9, 7, and 5 = 21, which taken from 30 leaves 9, and this added to 3, 2, 8, and 9, we obtain 31; write 1, the difference of the two columns. This may be briefly shown as follows: $30 - 21 + 22 - 30 = 1$. Adding and subtracting 30 does not affect the result. (2) $4 + 3 + 8 = 15$; $20 - 15 = 5$; $5 + 7 + 3 + 7 + 5 = 27$; write 7. In the same manner add the remaining columns. In the last column we subtract 10 after adding to upper column, since we added ten before subtracting.

(2) We next take a case where it is necessary to carry, which involves the only difficulty in the operation. Let it be required to subtract the sum of B from A.

$$\left.\begin{array}{r}87642\\58831\\69346\end{array}\right\}A$$

$$\left.\begin{array}{r}34598\\3276\end{array}\right\}B$$

$$\overline{177945}$$

(1) The sum of 6 and 8 is 14; 20 — 14 = 6, which, added to 6, 1, and 2, we obtain 15.

Since we used one more ten in *B* than in *A*, we carry 1 to the next column *B*. (2) 7 + 9 + 1 = 17; 20 — 17 = 3, which, added to 4, 3, and 4 = 14; write 4 for second figure of the result. Again, one more ten is used in *B* than in *A*. In fourth column one more ten is used in *A* than in *B*; in this case we subtract 1 from *B* before taking the sum from the next higher number of tens. Hence, if the excess of tens is greater in *A*, subtract the excess from next column of *B*; if the excess of tens is greater in *B*, add the excess to next column of *B* and proceed as before.

BANK ACCOUNTS.

In these examples the deposit in the bank is first written, and beneath the several checks drawn on the deposit. The final balance is required.

$$\begin{array}{r}\$326.48,\text{ deposit.}\\ \left.\begin{array}{r}18.64\\4.50\\12.84\\32.16\end{array}\right\}\text{checks.}\\ \hline \$258.34\end{array}$$

$$\begin{array}{r}\$465.76\text{ deposit.}\\ \left.\begin{array}{r}24.65\\18.20\\38.45\\63.84\end{array}\right\}\text{checks.}\\ \hline \$320.62\end{array}$$

$$\begin{array}{r}\$500.00\text{ deposit.}\\ \left.\begin{array}{r}104.86\\26.20\\92.07\\6.96\\14.32\end{array}\right\}\text{checks.}\\ \hline \$255.59\end{array}$$

Short Cuts in Multiplication.

I.—To square a number of two or more figures.

(1) Square 76. Write the squares of the two digits, and beneath, twice their product, as shown in the model.

Operation.

$$\begin{array}{r} 76 \\ 76 \\ \hline 4936 \\ 84 \\ \hline 5776 \end{array}$$

(2) Square 475. In this case write the squares of the digits in their order, and beneath, twice the product of first and second, second and third; lastly, twice the product of first and third digits, as shown in the operation.

Operation.

$$\begin{array}{r} 475 \\ 475 \\ \hline 164925 \\ 5670 \\ 40 \\ \hline 225625 \end{array}$$

This method avoids any carrying in the process of multiplying.

SECOND METHOD.

II.—To square a number of two digits:

Square the first digit, beginning at the right, take twice the product of the two digits, and the square of the tens digit, carrying when necessary.

$24^2 = 576$; $4^2 = 16$; 8 times $2 + 1 = 17$; $2^2 + 1 = 5$.

III.—To square any number ending in 25. (1) If the part to the left of 25 is even, to its square add its half, and prefix to 0625. (2) If the part to the left is odd, to its square add its half less one, and prefix to 5625.

ILLUSTRATIVE PROCESSES.

$825 \times 825 = 680625$. $8 \times 8 + 4 = 68$, which prefix to 0625.

$725 \times 725 = 525625$. $7 \times 7 + \frac{1}{2}(7 - 1) = 52$, which prefix to 5625.

IV.—In squaring a number of three figures, if a cipher intervenes, write the square of units' digit, twice the product of the two, and square of hundreds' digit; no carrying being required.

$$705 \times 705 = 497025.$$

Square: 804; 905; 608; 508.

V.—Combining this principle with the previous case, square 204025.

Operation.

$$\begin{array}{r} 204025 \\ 204025 \\ \hline 41{,}626{,}200{,}625 \end{array}$$

40 times $40 = 1600$, to which add $\frac{1}{2}(2040)$, obtains 2620; 204 times $204 = 41616$.

VI.—To square a number ending in 5.

$45^2 = 2025$. 4 times $(4 + 1) = 20$, which prefix to 25. Multiply the tens digit by a number one greater, and prefix to 25.

Square: 65; 85; 115; 75; 95; 195.

VII.—The product of two numbers which differ by two is equal to the square of the intervening number, less one, or the square of one-half their sum less one.

$$24 \times 26 = [\tfrac{1}{2}(24 + 26)]^2 - 1 = 25^2 - 1 = 624.$$

VIII.—Any two numbers may be multiplied by using the complements of the numbers.

Applied to numbers less than 100: multiply 98 by 96.

$$\begin{array}{r} 98 \ldots\ldots\ldots 2 \\ 96 \ldots\ldots\ldots 4 \end{array}\Bigg\}\ \text{Complements.}$$

$$\begin{array}{r} \hline 9408 \end{array}$$

(1) Multiply the complements for the two final figures of the product, supplying a vacant place, if any, with a cipher. (2) For the final figures of the product subtract one of the complements from the other number; thus, $98 - 4$, or $96 - 2 = 94$.

CABLE TRACTION AS APPLIED TO ELEVATED RAILROADS.

BY CHAS. W. THOMAS, M. E., '84.

(Continued from page 233, Vol. VII.)

THE elevated structure and its rolling stock adapted to the cable system can be made to conform more easily to the requirements of city streets than any other system; curves can be made of smaller radius without greater wear to either cars or motor, and the structure less cumbersome in design, due to the absence of heavy strains caused by the locomotives in starting; all stations can be made easy of access, and far less objectionable to the residents along the line. One disadvantage, however, has been the "hum" produced by the cable striking on the carrying sheaves. Figs. 1, 2, and 3 rep-

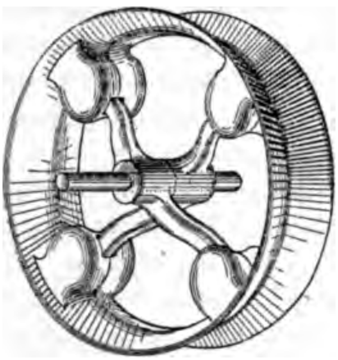


FIG. 1.

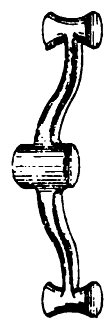


FIG. 2.

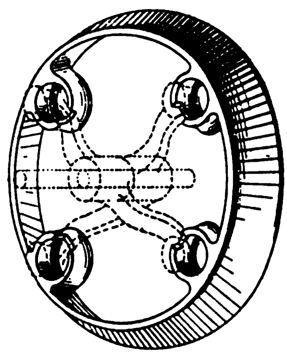


FIG. 3.

resent a new and improved form of wheel; it consists of two arms, which are bored and driven on the shaft; at the ends of the former are conical shaped projections which set in sockets cast in the half rims; the parts are held in proper position by a suitable jig, when a non-resonant material, such as lead or babbit metal, is poured between them and allowed to cool, thus firmly uniting the hubs and rims. The pulley is now placed on centres, balanced, and ground true on an emery-wheel, which, at the same time, produces a polished surface upon which the cable runs practically noiseless.

The next problem is to design the power house so that it can be erected on two city lots, or a space of 50 feet by 100 feet. Although the writer has never seen the same in operation, yet from the present tendency of engineering to use high steam pressures and triple expansion engines, it would, no doubt, be an economical step to adopt one of the marine types of engines, where economy of space enters as an important factor. For such a plant two vertical triple expansion engines of 1,000 horse-power each, so arranged that each engine could operate independently either set of driving machinery, would make with the safety devices, now patented, a most complete plant, capable of operating about three miles of road.

There are several types of driving drums and several methods of transmitting power to the same, but the best practice appears to advocate the use of cotton-rope belts. The tension carriage has been somewhat troublesome on account of the pit required for it, and also the space it occupies. However, these disadvantages have been given careful thought and, no doubt, before long, some new improvements will be in successful operation.

The boilers would have to be arranged to best suit the space allotted to them ; if head room is abundant and floor space cramped, such a class of boilers as the Hazleton or Manning might be used. Where the boilers can be placed below some parts of the driving plant, the horizontal tubular or a sectional boiler would be better adapted.

The safety devices for cable roads consist of means of communicating from any point along the road to the power house. This is usually accomplished by a double wire running parallel to the track, or by a single wire, using the rail as a return. In circuit with the same is a primary battery, furnishing the requisite power to operate the electro-magnets, which control the steam and brake valves, and also give a signal to the engineer. The operation is as follows: should any accident occur on the road, the gripman, by means of a lever attached to the car, presses a metallic shoe upon the wire or wires, thereby closing the circuit,—in the case of the single wire,

through the medium of the rails and wheels. When the circuit is closed the two electro magnets become energized; the first of these rings an alarm upon a bell, and the second operates a small valve, which allows steam or compressed air to act upon a piston controlling the main steam valve of the engine, shutting off the steam from the same. When the valve controlled by the electro magnet opens the steam or compressed air valve, steam or air, as the case may be, flows through a second pipe into a pair of single acting cylinders which control the brake shoes on the fly-wheel of the engine, so that the gripman, from any portion of the road, can stop the engine without the delay of signaling the engineer, and then waiting for him to shut off the steam and to apply the brakes.

In conclusion, it should be stated that there is room for the cable system, as well as for the systems in which electricity or steam is the motive power; and when the cable system has been developed from some of the present crude stages, there is no reason why it should not compete with any of the existing systems of traction. In one point it has proved itself superior to one of its rivals, for during a heavy snow-storm it operated with the same regularity as on a midsummer day; this was not the case with electric traction.

MARINE GOVERNORS AND THE CAUSES OF THEIR FAILURE.*

BY J. HANSEN, '91.

WHEN crossing the Atlantic last summer, I had occasion to experience the bad effects resulting from the racing of the engines in rough weather. Although a man was stationed at the throttle all the time, it was occasionally impossible to control the speed of the engines so that they would run smoothly.

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* Read at the meeting of the Stevens Engineering Society, November, 1890.

When the propeller emerged completely. the engines doubled their speed, and the whole ship would quiver as if struck by a breaker. The increased speed of the engines and the vibrations of the ship were, of course, very injurious to both structures. You will naturally ask why the engines were not provided with a governor to prevent their racing. They did, in fact, have a governor, but it could not regulate the speed, and I was informed that no governor yet invented was satisfactory for ocean steamers.

On small steamers, however, several of the patented governors have been known to work very well. We know, also, that governors can properly regulate stationary engines subjected to great variations of load, as, for instance, engines driving mill trains. Let us, therefore, see why they fail in large marine engines.

Stationary engines generally have the fly-wheel to draw upon as a reservoir of energy; to change the angular velocity of this large mass a noticeable amount, an appreciable time is required, and, besides, the ball governors being very sensitive, the desired regulation can be effected. But in marine engines the fly-wheel cannot be used, as it occupies too much space, and, above all, does not permit of a speedy reversal of the propeller. Then, too, ball governors become so easily deranged when the ship rolls or pitches, even when they are independent of gravity, that they may be considered unsuitable. Let us next determine to what extent a fly-wheel regulates the engine. In a marine engine the propeller and shaft act, in a degree, as a fly-wheel, but we will find that their mass is much too small to check the rapid increase of speed when the resistance is diminished. An engine of 1,500 indicated horse-power would require a fly-wheel having a weight equivalent to 100 tons at a radius of 6 feet, the number of revolutions being 60 per minute.

The propeller will be regarded as a fly-wheel weighing 16 tons acting at a radius of 6 feet, this being the estimated radius of gyration of the screw.

Having the weight of the pistons, shafts, etc., and remembering that the masses are obtained by dividing the weights by 32.2, we find the energy stored in the revolving masses, neglecting the connecting rods and cranks, to be :

With the fly-wheel, 4,360,000 foot-pounds nearly

" " propeller, 740,000 " " " the speed in both cases being 60 revolutions per minute, and the shaft having two cranks at right angles. If the engines are now suddenly

relieved of their load, let us see what their angular velocity will be after three seconds, which is about the length of time the propeller may be out of water in a storm. If there were no friction, and no diminution of the energy exerted by the steam, $550 \times 1{,}500 \times 3 =$ 2,475,000 foot-pounds would be developed in three seconds. Assuming that the friction or "dead load" is 13 per cent. of the energy (13 per cent. being an average value), 2,150,000 foot-pounds remain to be absorbed by the moving parts, neglecting, as before, the connecting rod and cranks, these being comparatively small. At the end of three seconds the energy stored will be:

With fly-wheel, 6,510,000 foot-pounds
" propeller, 2,890,000 " "

this result being obtained by adding 2,150,000 foot-pounds to the values given above. Placing each of these values equal to the expression of stored energy, involving the angular velocity as the only unknown quantity, we find that after three seconds the engine, with the fly-wheel, would acquire a velocity of 73 revolutions per minute, and with the propeller, a velocity of 119 revolutions per minute. This latter result agrees with the actual speed occurring in steamers when the screw emerges, so that our assumption that the energy exerted by the steam does not diminish in three seconds is probably correct. You clearly see, therefore, that there is a great difference in the times that a stationary and a marine governor must act to limit the speed to a certain number of turns. At the end of three seconds the marine engine would have doubled its ordinary speed, while, if fitted with a fly-wheel, the velocity would have increased but 20 per cent.

A good marine governor should, without the aid of a fly-wheel, regulate as effectively as an ordinary governor. It must, above all, be very sensitive, for if it does not act upon the throttle until the velocity of the engine has considerably increased, a further increase of velocity will occur before the action of the governor can be effective.

In connection with the sensitiveness of the governor, the proportions of the steam chests and receivers must also be considered. These parts must be made as small as possible, otherwise the throttling, however quick, will not be efficient. In compound or triple expansion engines this point is very important; as the steam is only cut off from the high pressure cylinder sufficient steam is supplied to the intermediate and low pressure cylinders, after being thus

cut off, to enable the engines to run for some time longer, particularly if the receivers are large.

A perfect marine governor should also be uninfluenced by the action of gravity, allow the number of revolutions to be varied, and the change from one constant speed to another to be made rapidly, and should work satisfactorily when the engines are suddenly reversed.

The existing governors can be divided into two general classes: those that only prevent racing in a rough sea, and those that check a change of velocity due to any cause whatever. Regulation is effected in both classes by throttling.

The first class includes those governors which depend for their action upon the immersion of the stern, while the second class is actuated by the varying motion of the shaft. Governors of the latter class cannot act until racing has commenced, while those of the former anticipate and check the variation due to pitching.

If the shaft should break, as in the accident that occurred to the "City of Paris," or the "Denmark," the immersion governor would be useless. Governors actuated by the variation of speed are, therefore, much to be preferred, and may be made to act very quickly and work well on small steamers. Their failure to work satisfactorily on large engines is due to the fact that the governors are not powerful enough to work the throttle. On this account it has been found necessary to connect the governor with the valve of a small steam cylinder, whose piston-rod, in turn, operates the levers attached to the throttle of the large engine. It is evident that this extra steam cylinder diminishes the rapidity of action, and by so doing seriously impairs the usefulness of the governor. This fact explains why the same style of governor is a success on a 600 indicated horse-power steamer, and a useless attachment on a 1,500 horse-power steamer, the type of engine being the same in both cases.

Governors depending for their action upon the immersion of the stern can, as stated above, only check racing due to pitching, and for this purpose have been quite successful. The principal types of this class are those invented by Dunlop, of which the Coutt & Adamson governor is a modification, and Smith & Pinkney's pendulum governor.

The "Dunlop" consists of a large vertical pipe running to the bottom of the stern of the vessel; this pipe is connected with a cylinder in the engine-room. The top of this cylinder is a steel

or rubber diaphragm, to the middle of which a rod is connected, which, by means of levers, operates either the throttle or the valve of an auxiliary cylinder. This governor seems to be applied extensively even on the most recent additions to the Transatlantic fleet. Its usefulness depends in a great measure upon the skillful arrangement of the apparatus. On the "Normannia" this governor is fitted to the engines, and is used much, but is unreliable in a heavy sea; at such times the throttle must be operated by hand. The "Augusta Victoria" is also provided with this style of governor, as are also the new steamers "Spree" and "Havel," of the North German Lloyd. In a large steamer the air pressure in the governor is about 12 pounds per square inch, while in smaller steamers the governor will regulate the engines with a pressure as low as 5 pounds per square inch.

The "Columbia" and "Russia" have improved forms of the "Coutt & Adamson" governor which work quite satisfactorily. This governor consists of a diaphragm which operates the piston valve of a steam cylinder. It does not differ in principle, but only in mechanical detail, from the ordinary Dunlop governor. The "City of New York" and "City of Paris" are also provided with Dunlop governors.

The "Smith & Pinkney" governor consists of a heavy pendulum, capable of swinging parallel to the length of the ship. In its original form the pendulum controlled a valve which allowed air to act on the piston of a cylinder, which was connected with the vacuum pump. Air was admitted when the ship began to pitch, and exhausted into the vacuum pump as soon as the ship returned to an even keel. The piston rod of the cylinder operates the throttle. While this governor works well in a heavy head sea, it is evident that a large steamer in a short sea, as on the great lakes, may be only slightly inclined, and the propeller be out of water, or there may be a heavy following sea, and the emersion also occur; in such cases the governor fails. Another objection to this governor is that it impairs the vacuum and charges the feed water with air; this defect has, however, been obviated by using steam instead of air.

The second class of governors — those in which the regulation depends upon the varying velocity of the shaft — includes many different types, but, unfortunately, they are not satisfactory. This class may be divided as follows:

1. Those using the inertia of a heavy wheel as a regulating power. 2. Pneumatic governcrs. 3. Hydrcstatic governors.

4. Those using fans revolving in air or in some liquid. 5. Centrifugal governors.

1. Governors using inertia, or, rather, the unwillingness of a heavy wheel to change its speed rapidly, are of little importance and can only be used on small engines.

2. Pneumatic governors, with the exception of the Dunlop governor, which may be included under this head, have given very little satisfaction; they generally regulate by means of the variation of pressure in an air pump driven by the shaft.

3. Hydrostatic governors are actuated by the variation of

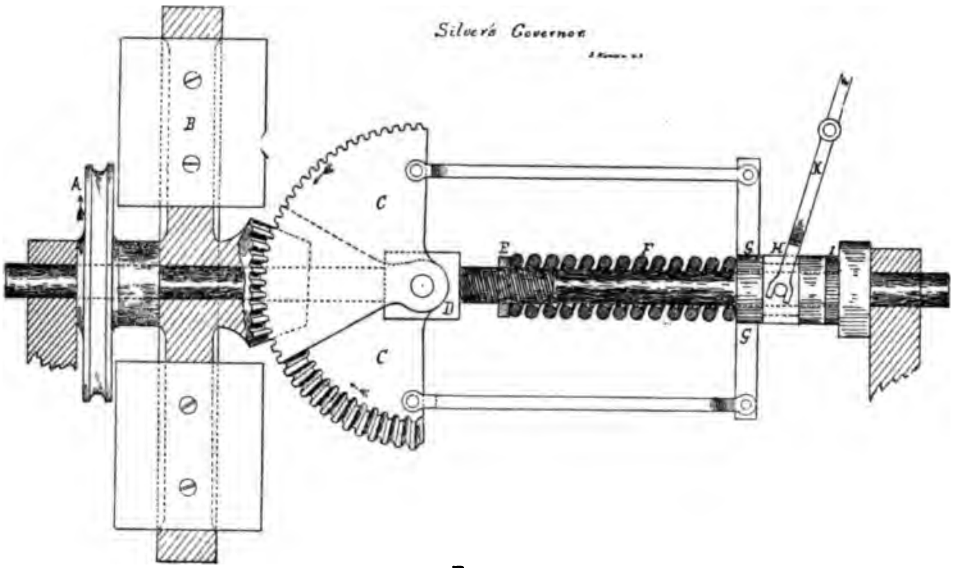

FIG. 1.

pressure of the water from the circulating pump. This pressure varies with the number of revolutions of the engines, and, owing to the air chambers, is quite uniform for a given speed. It can only be used when the pumps are driven from the cross-head, which is the case in some of the largest and fastest steamers.

4. Mechanisms fitted with paddle-wheels revolving in air or a liquid include several that have been successful, if any marine governor can be called a success.

The "Allen" governor consists of a paddle-wheel revolving inside a cylinder, the inner surface of which is corrugated; the

cylinder is horizontal and half filled with oil, whose force of impact on the cylinder is kept in equilibrium by a spring acting on its circumference. A lever attached to the cylinder operates the throttle; this governor has too little power for big engines.

The "Silver" governor (Fig. 1) has been used on several Transatlantic steamers with good results.

A is a pulley keyed to shaft; B, a fly-wheel with vanes and pinion, looseon shaft; C, bevelled sectors pivoted at D, part of shaft; E is a nut for tightening spring F, abutting against sleeve G, which is compelled to turn with shaft, but which can slide towards D. A strap H operates the lever of the throttle. I is a rubber cushion

·Durham & Churchill· Governor.

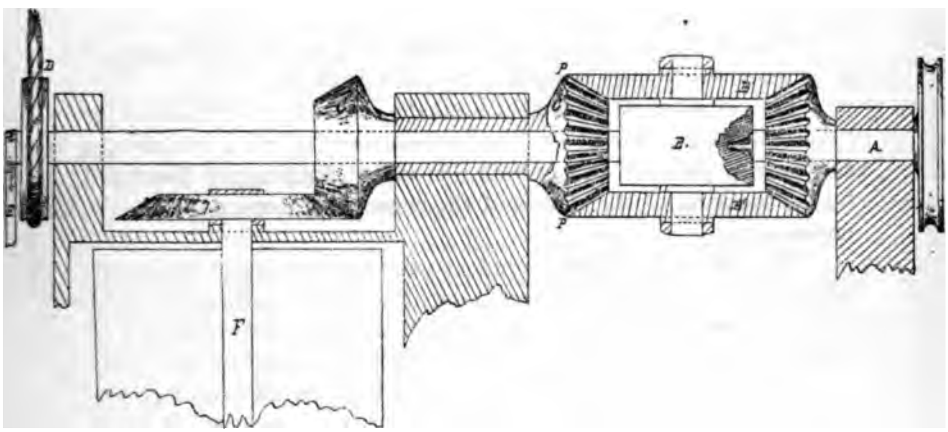

FIG. 2.

for diminishing shock when governor is stopped. Suppose the governor revolves uniformly; G will then be nearer to E than when at rest, for F will have to supply the force to keep B revolving with the other parts. Next, suppose an increase of speed; B will not respond and the pinion will lag behind, the result being that C is drawn in the direction of the arrows, and a corresponding motion of K takes place. Throttling occurs, and G is brought to its former place.

The action of the "Durham & Churchill" governor (Fig. 2) depends upon the variation of pressure due to the varying speed of a paddle-wheel in a liquid.

A is a shaft with driving pulley; B is block, part of other length of shaft having trunnions for bevel-wheel B′; C, bevel-wheels connected by hollow shaft; D, prony brake; E, lever which operates valve of auxiliary cylinder; F, paddle-wheel revolving in oil. To adjust the governor for a certain speed, the brake is tightened until B does not revolve; then the force applied at the brake P is just balanced by resistance to F in the oil. If the engine, and, therefore, A goes faster, the resistance to F increases; but D cannot supply a greater force, hence B, and therefore E, is turned and operates the throttle. This governor is said to work satisfactorily.

The "Westinghouse" marine governor consists of a small, sensitive centrifugal governor, which operates the valve of a steam cylinder whose piston is connected with the throttle. It has been applied to several steamers, but engineers do not consider it reliable.

The problem of a satisfactory marine governor, although of great importance, may be said to be still unsolved.

The number of steamers annually recorded as disabled, or "never heard of," would be greatly diminished if this problem were successfully solved. It is certain that many steamers are destroyed by the breaking of the shaft and the consequent breakdown of the engines.

Many able engineers have endeavored to overcome the difficulties, as the subject is also one of great importance from a financial point of view. Some one has suggested that when the governor cuts off the steam it should also be made to apply a brake to the shaft. This idea is worthy of consideration. The governor might also be designed to throttle all passages in the engine through which steam is admitted to perform work.

NOTE ON THE PERFORMANCE OF THE DOUBLE SCREW FERRY BOAT "BERGEN."

AFTER substituting corrugated furnaces for those of the plain cylindrical form, which was the only feature of the boat not entirely satisfactory, the "Bergen" had been constantly in service, on the mile and one-half route from Barclay Street, New York, to Hoboken. After 106 days of such service the boat was

"laid up," to undergo the general inspection and overhauling to which it is customary to subject all of the ferry boats every three months; and was fitted with wheels 8 feet in diameter and 10 feet pitch. The original wheels are 8 feet in diameter and 8.7 feet pitch. These wheels were in no way defective, but their comparatively fine pitch, which was regarded as a safeguard against excessive vibration when the engine was reversed in entering the slip, required a speed of rotation undesirably high.

The absence of any disagreeable vibration with these screws, however, encouraged the belief that a greater pitch could be used with advantage, and consequently it was decided to try such screws.

The boat has now been using the new screws about three weeks, with entire success so far as freedom from vibration is concerned, and so far as can be judged in intermittent ferry service, a greater speed of propulsion is obtained, at a reduced speed of rotation of the engine.

The presence of drift ice in the river for the first time since the "Bergen's" completion, has afforded the long-desired opportunity of trying the ability of her double screws to encounter and remove the ice which has recently clogged the slips on the New York side of the ferry. The following communication from Superintendent Woolsey gives an interesting account of the behavior of the boat in the midst of the ice:

HOBOKEN, N. J., January 21, 1891.

PROF. J. E. DENTON,
Stevens Institute, Hoboken, N. J.

MY DEAR SIR: It affords me great pleasure to give you information concerning the operations of the "Bergen" in the ice.

This winter has given us the first opportunity of testing her qualities under such conditions since she was built.

After having changed her wheels and doing some overhauling to her machinery, I took her out in the river to give her a thorough test in the ice before placing her on her regular route. On this occasion I took pains to put her through all of the ice fields that I could find, and they were many and very tough. Her performances in the ice fields are particularly satisfactory; and at no time while

going through fields of large area, and estimated to be six to eight inches thick, did she reduce her speed less than one-half. Her maneuvering qualities were particularly gratifying, and we found ourselves able to turn almost as short a circle in the ice fields as in clear water. Her value in the slips has been thoroughly tested; and on the date to which I refer, we put her in a slip where no boat, for twenty-four hours, had been able to reach the bridge on account of the ice massed between the racks. The "Bergen" went up to the bridge without the slightest difficulty, and, remaining there fifteen minutes with her engines working, completely cleared the slip of ice; so free, indeed, that it would have been possible to have rowed a small boat up to the bridge.

She has since that time been in continuous service, and is doing most satisfactory work.

The slips in which she runs are kept clear of ice, or, more properly speaking, the ice is kept loose and in motion by the action of her wheels, so that no difficulty whatever is experienced in reaching the bridge and handling her passengers and teams without the aid of gangplanks. In short, she has fully reached our expectations as an ice-boat.

Knowing your great interest in all her performances, I send you this information that it may complete, in your mind, the full history of her performances since she was put in service.

I am, yours truly,

[Signed] C. W. Woolsey,

Superintendent.

Captain Woolsey intends to make a careful trial of the action of the new screws over a measured course, as soon as the weather and the exigencies of the ferry service permit.

Huge Lathes and Cranes Operated by Electricity.—We see from an article in the Philadelphia *Ledger* that "the Government has awarded a contract for eight lathes to William Sellers & Co., Inc., of this city, and adopted the design of that corporation in preference to those of the Government engineers and of other competitors. This probably did not attract much attention from the public, but it is none the less an important item to the industrial com-

munity of this city. These tools are intended for turning and boring guns; they will cost over $400,000, and an idea of the size of the machines may be formed when it is stated that one of the lathes will weigh about 500,000 pounds, or 250 net tons."

In the same article, which contains a description of portions of the Sellers' works, we see that there are in use in that establishment several large traversing cranes capable of carrying 20 tons or more, which are operated by electric motors located on the cranes, the current being conveyed through a wire from a distant dynamo. The article says:

"These cranes are operated by an electric current from a dynamo, and it is difficult to realize that the power necessary to move such heavy masses is all conveyed through a wire not thicker than a slate pencil.

"The bridge can move on the 'run way' at the rate of 200 feet a minute; the trolley can run back and forth on the bridge at the rate of 100 feet a minute, and at the same time it can wind up the chains, with a load attached, at the rate of 40 feet a minute."

In this connection it is interesting to note that at the Baldwin Locomotive Works in Philadelphia, an entire workshop which has recently been added to the immense plant, and which was before turning out more than two locomotives a day, has been fitted up with tools driven by individual electric motors forming part of each tool, the "power" being in all cases transmitted by an electric current flowing in wires and not by shafting or belting.

The Number and Magnitude of Molecules.—It is not proposed in this place to make any reference to the elaborate arguments by which the size and number of the ultimate molecules constituting material bodies have been approximately determined, but only to put on record, so that they can be readily referred to, some interesting and striking statements which have appeared in publications not readily accessible.

In the first place, as to the number of molecules. In a lecture delivered to the British Association for the Advancement of Science,

August 22, 1879, Dr. William Crookes says, near the conclusion, in reference to one of the globes, highly exhausted so as to develop the phenomena often described as those of radiant matter:

"According to the best authorities, a bulb of the size of the one before us, 13.5 centimetres in diameter (about 4 inches), contains more than 1,000000,000000,000000,000000 (a quadrillion) molecules.

"Now, when exhausted to a millionth of an atmosphere we shall still have a trillion molecules left.

"To suggest some idea of this vast number, I take the exhausted bulb and perforate it by a spark from the induction coil. The spark produces a hole of microscopical fineness, yet sufficient to allow molecules to penetrate and to destroy the vacuum.

"Let us suppose the molecules to be of such size that every second of time a hundred millions could enter. How long, think you, would it take for this small vessel to get full of air, after having been thus partly emptied? An hour? A day? A year? A century? Nay, almost an eternity! A time so vast that imagination itself cannot grasp the reality. Supposing this exhausted glass globe, indued with indestructibility, had been pierced at the birth of the solar system; supposing it to have been present when the earth was without form and void; supposing it to have witnessed all the stupendous changes evolved during the full cycles of geologic time, to have seen the first living creature appear and the last man disappear; supposing it to survive until the fulfillment of the mathematician's prediction that the sun, the source of energy, four million of centuries from its formation will ultimately become a burnt-out cinder; supposing all this — at the rate of filling I have just described, 100 million molecules a second—this little bulb, even then, would scarcely have admitted its full quadrillion of molecules."

"But what will you say if I tell you that all these molecules, this quadrillion of molecules, will enter through the microscopic hole pierced in the bulb by the spark before you leave this room? This apparent paradox can only be explained by supposing the size of the molecules to be diminished almost infinitely, so that instead of entering at the rate of 100 *millions a second*, they troop in at the rate of something like 300 *trillions a second*."

In a foot-note to the above Dr. Crokes says:

"According to Mr. Johnstone Story, Phil. Mag. Vol. 36, p. 141, one cubic centimetre of air contains about 1000,000000,000-

000,000000 molecules. Therefore, a bulb 13.5 centimeters diameter will contain, at atmospheric pressure, $13.5^3 \times 0.5236 \times 10^{20}$, or 1,288252,350000,000000,000000 molecules. Therefore the bulb, after exhaustion to the millionth of an atmosphere, contains 1,288-252,35000,0000000 molecules, leaving 1,288251,061747,650000,-000000 molecules to enter through the perforation. At the rate of 100,000000 molecules a second the time required for all to enter will be:

12882,510617,476500 seconds,
or 214,708510,291275 minutes,
or 3,578475,171521 hours,
or 149103,132147 days,
or 408,501731 years."

Magic Square for 1891.—It has been generally claimed by mathematicians that a magic square cannot be formed of an "even root" whose numbers, added in the usual way, will give an odd number for the sum. This is, however, possible, as will be seen in the accompanying example by Prof. H. A. Wood. If the numbers composing the square be added vertically, horizontally or diagonally, the sum in each case is 1891. The same result is obtained by adding the numbers in the corners, the four numbers composing a corner, or the four numbers in the centre.

1891

	1000	707	103	81	
	101	83	1007	700	
1891					1891
	87	100	701	1003	
	703	1001	80	107	

1891

OBITUARY.

HENRY SUYDAM, M. E., '78.

HENRY SUYDAM died at Newark, N. J., on November 25, 1890, at the age of 31 years, having been born in New York City, April 29, 1859.

His family removed from Newark, where they had previously resided for thirteen years, to Hoboken, solely on account of the

educational advantages offered by the Stevens Institute and the German Academy of this city. He attended the latter school prior to entering the Institute in September, 1874; joining the Class of '78 he graduated in June, 1878, receiving the degree of Mechanical Engineer.

As a student his record was highly creditable and gave every promise of a successful professional career. He was popular with his classmates, and took an active interest in athletics, having been a member of the college foot-ball and base-ball teams.

After graduation he entered the employ of the Pennsylvania Railroad Company and for two years was located in the "Meadow Shops," and also for a short time at the Altoona shops of this road.

He then went West and accepted a position with W. H. H. Bowers, contractor for the Moulton & Alice and other mines, by whom he was employed, together with Mr. W. E Jacobs, '79, as draughtsman.

About two years later he entered the employ of the Denver and Rio Grande Railroad, taking charge of construction work and finally of buildings, etc., at the Salt Lake City terminus.

About seven years ago he returned East and took employment with the Newark brewers, P. Ballantine & Sons, whom he served in various capacities; his previous training and experience enabled him to render valuable services in superintending the construction of buildings—malt-houses, grain elevators, etc.—and in the erection of an ice plant which was introduced last spring, and of which he had entire charge when it was put in operation.

It was while thus engaged that he was stricken down with typhoid fever, to which disease he fell a victim after an illness of three weeks.

The deceased was married and leaves a wife and two children. The funeral services were held at the Trinity Episcopal Church, Broad Street, Newark, on November 28.

ATHLETICS.

The outlook for athletics at the beginning of the present season was very discouraging. Interest in college sports, which had been waning for the past two years, seemed to have reached its lowest ebb. So low, indeed, that, notwithstanding the number of men in the Institute who play foot-ball, the management found it impossible to get together enough good players to form a creditable team. Therefore, rather than put a weak team in the field and have the season drag along to an inglorious close, they concluded to withdraw from the league for one year. Meanwhile, in order to foster whatever interest might still be left, it was determined to hold an interclass series of games for the championship of the Institute. This has been unexpectedly successful. The drastic remedy of resigning our place in the league proved the desired tonic, and the men who had never given a second thought to the 'Varsity, now came forward and worked hard for the success of their respective classes. The playing of the teams has been excellent, and the support given them by the college most encouraging. Instead of its being difficult to get enough men together to raise a college cheer, as in former years, this fall the field has been lined with the enthusiastic friends of the different classes.

It is to be hoped that the success of these games indicates the revival of a healthy interest in college sports. In the past these have fulfilled a two-fold end. First, that of providing the outdoor exercise, so necessary for the best and fullest development of a man, and second, the promotion of college feeling. In a college like ours, with no dormitories, and but little chance for social intercourse, anything that stimulates college pride and binds the students closer together in a common interest, not only benefits us but fosters that love and support of our Alma Mater that will be valuable to her when we have taken our places in the world.

It is, therefore, encouraging to note the renewed interest in foot-ball, and to record the bright outlook for next year. The present season has clearly established the fact that there is plenty of good material in the college, and while we have neither the time nor money to compete with larger colleges, we ought not to find it difficult to meet those of our own size as equals.

The series of interclass games, as arranged, resulted as follows·

Oct.	30,	'92 *vs.* '94		20–8
"	31,	'91 " '93		0–0
Nov.	3,	'92 " '93	Tie	13–12
"	7,	'91 " '94		18–0
"	10,	'93 " '94		12–0
"	19,	'92 " '91		6–0
Dec.	1,	'92 " '93 to play off tie		6–0

'92 won the championship, scoring 3 games won, none lost; '91 and '93 tied for second place, each winning one game, tieing one, and losing one.

The championship banner has been hung in the library. It is about 4x6 feet, and is made of pearl grey silk, embroidered in crimson, with the following inscription:

"STEVENS INSTITUTE,"
INTERCLASS CHAMPIONSHIP, SEASON 1891.
WON BY CLASS OF '92.
Strong, Waefeler, Wells, Whitcomb, Schaeffer, Macy, Vogelius,
Wettlaufer,
Hake, Cuntz,
Post.
Subs.—Harrison, Cohen, Jackson, Meyer.

Below we give a brief account of the more interesting games.

'91, 0—'93, 0. This was one of the most interesting games of the series. Both sides were very evenly matched. The ball seldom got beyond the 25 yard lines, and constantly changed hands on four downs. Time was called without either side having been able to score.

'92, 13—'93, 12. Declared a tie.

Both classes put up a first-rate game, characterized by fine team work. The playing together of Wettlaufer, Hake and Cuntz, '92, was especially good. MacCord carried off the honors for '93, by a magnificent run for goal from the middle of the field. '93 scored her first touchdown and goal by repeated rushes through the centre; and her second by MacCord's run. '92 secured one touchdown by fine team play, one by hammering the centre, and finished by trying for a goal from field. This was apparently successful, and the umpire awarded her the game by a score of 13 to 12. On '93's protest, however, the Executive Board of the Athletic Association declared the game a draw, and it was played off December 1.

'92, 6—'91, 0. '92 started off in good shape, carrying the ball close up to '91's line, and soon forcing Darby to make a safety. On bringing the ball out they again forced the playing and sent Macy through the centre for a touchdown, but failed to kick goal. No further scoring was done during the game. '91 played better in the second half, and tried hard to tie the score. Several times they forced the ball dangerously near to '92's line, but failed each time to carry it over.

'93, 12—'94, 0. This was the annual Sophomore-Freshman game, and was marked by the usual amount of enthusiasm, the friends of both classes turning out in full force. The game was well contested, and neither side scored in the first half. In the second, the superior weight of '93 told, and fine rushes through the centre by MacKenzie scored her three touchdowns. MacKenzie and Griswold did the best playing for '93, and Fielder, Coyne and Maynard for '94.

'92, 6—'93, 0. This was the final game of the season, and was played to decide the tie between the two teams. As in the game with the Seniors, '92 started off by forcing the playing, and good rushes by Hake and punts by Post, soon brought the ball near '93's line. Vogelius carried it over, and scored the touchdown. On bringing the ball out '93 did some fine work, but their gains were neutralized by runs for 30 and 50 yards by Wettlaufer

and Hake. The second half was characterized by exceptionally good playing by '93. They gained largely through the centre, and interfered so well as to send MacCord around the end for 40 yards, finally bringing the ball to within a few feet of the line. Here '92 made a desperate stand and for six downs prevented '93 from scoring. '92 then forced the ball out somewhat, but fine runs by MacKenzie brought it back and enabled him to try for goal from field. This failed, and time was called with the ball again close to '92's line; the Sophomores, notwithstanding their fine playing, having been unable to score.

'91 had the heaviest rush line, and they depended largely on it, sending their backs generally through the centre. '92 and '93 were stronger on the ends, and therefore kicked and ran around the ends more freely. '94 brought out some brilliant individual players, but her team work was poorer and her rush line lighter.

It is much to be regretted that Amherst was obliged to cancel her game with us for Thanksgiving Day, as our team would doubtless have made a splendid showing.

When the Executive Board of the Athletic Association decided that Stevens should put no foot-ball team in the field this fall, our delegates to the convention were instructed to arrange the most favorable conditions by which we might keep our place in the league, and yet play no games this year. But this proved a harder task than was expected, for the other colleges insisted that there must be five, and only five, colleges in the league. So it seemed for a time as if we would have to either resign entirely, or else accept the hard alternative of forfeiting all our games, and paying the forfeits. Finally, however, the following resolution was passed:

"That Stevens be allowed to resign for one year; the question of her re-admittance next fall being left to a vote of the four other colleges; the vote, in case of a tie, going to Stevens. Also, that Bowdoin be admitted for one year only, to fill Stevens' place."

Therefore, if two of the four colleges stand by us next year, as we do not doubt that they will, the question of our re-entering the league rests entirely with ourselves. Hard and enthusiastic work will insure our success, but such a lack of interest as was shown this fall would mean our being passed over in favor of some more active and enterprising rival.

It therefore behooves every man who desires to see a Stevens 'Varsity team in the field next fall to do what he can to help the sport along. If he can play, let him come out and practice when the teams are being chosen. If not chosen, then let him join the scrub and make the regular players work hard to defeat him. If he cannot play, he can certainly be present at the regular and practice games, for nothing so encourages a team to hard work as the feeling that their fellow-students appreciate their efforts.

Grounds.—It is now certain that the Hoboken Land and Improvement Company will lease the athletic grounds to the trustees of the Institute. The trustees cannot be praised too highly for their generosity in this

matter, as otherwise the grounds would have been let to some athletic club and the Institute would have had no use of them at all. The trustees will sublease to the St. George Cricket Club on somewhat the same terms as heretofore, and the Stevens School will also be allowed the use of the grounds on certain days. Except that the association will lose the revenue derived from the rental the terms will be much better than ever before, as we will have more days, and the trustees will undertake entire charge of the grounds and all repairs. These alone will very materially reduce the loss of the rental.

THE scores of the games played by the Eastern Intercollegiate Football Association, from which Stevens resigned this fall, are given below:

November 1, at Hanover, Dartmouth *vs.* Bowdoin, 42—0.
" 1, at Boston, Amherst *vs.* Technology, 38—6.
" 4, at Portland, Williams *vs.* Bowdoin, 50—0.
" 8, at Boston, Williams *vs.* Technology, 36—0.
" 8, at Amherst, Amherst *vs.* Bowdoin, forfeited by Bowdoin.
" 15, at Williamstown, Williams *vs.* Amherst, 6—0.
" 15, at Hanover, Dartmouth *vs.* Technology, forfeited by Technology.
November 19, at Amherst, Dartmouth *vs.* Amherst, 4—0,
" 22, at Williamstown, Dartmouth *vs.* Williams, 0—6.
" 27, at Portland, Technology *vs.* Bowdoin, forfeited by Technology.

Williams won the championship, winning four games and losing none. No points were scored against her in the championship games.

OUR LACROSSE TEAM.—Although I was requested to write a short article for the INDICATOR regarding the prospects of the lacrosse team for the coming season, I can only say that it is as yet too early to form any opinion of the strength of the team. Judging from the good showing made by the team last spring, and as nearly all of that team are still in college, and from the excellent looking material in the Freshman class, it would seem that the prospects were never before so bright for a winning team.

If we wish, however, to put forward a winning team, it will be necessary, first, to destroy the idea prevailing in college that lacrosse is a game that is dying out. Nothing could be more absurd than this. It is a fact that there will be more lacrosse teams in and around New York next spring than ever before. The Manhattan, Staten Island, and New York Athletic Clubs will each put a strong team in the field, and the fact of the Amateur Athletic Union having recognized it as one of its regular sports, and established a series of championship games in the North, East and West, will give the game such support as to make it almost as universally played, and as much of a national game, as base-ball.

The action of Princeton in giving up lacrosse as a college sport has certainly been a blow to the game. But it must be remembered that the action was not taken on a majority vote of the students, but because it took a two-thirds vote to overrule the decision of the Athletic Committee.

Stevens should, I think, unquestionably remain in the lacrosse league. We will now compete only with colleges of our own standard in athletics—Lehigh and Johns Hopkins, and possibly the University of Pennsylvania. With so many teams in the vicinity of Hoboken with which to practice, with a large surplus in the treasury of the association—a fair part of which will be devoted to lacrosse—and with a big "brace up" in lacrosse enthusiasm around college, there is no reason why we should not this year win the pennant; and in the future, when lacrosse will be played by every college in the country, old Stevens will stand forth as the foremost champion of the game. CAPTAIN.

REPORT OF TREASURER OF STEVENS INSTITUTE ATHLETIC ASSOCIATION FOR YEAR ENDING JANUARY 13, 1891.

SUMMARY.

Receipts.

Former Treasurer of S. I. A. A.	$97.58	
St. George Cricket Club, '89—Rent	100.00	
" " " " '90— "	250.00	
Dues, 26 at $5 — $130; 63, at $3 — $189; Irregular, $8	327.00	
Due from St. George on '90 Rent	100.00	
Gate Receipts	102.55	
Rental of Lockers	22.25	
Rental of Grounds	22.00	
Entry Fees at Spring Games	14.50	
Minor Receipts	6.60	
		$1,042.48

Expenditures.

Lacrosse Team	$194.32	
Base-Ball	121.25	
Foot-Ball	32.80	
Moving of Locker House	40.00	
For Work and Materials at Grounds	35.64	
Interclass Championship Banner	35.00	
Lumber for Fence	25.00	
Plumbing	15.00	
Printing	14.75	
Fitting up Lockers	11.84	
Intercollegiate Association Dues	10.00	
Tennis Nets	9.30	
Medals	7.50	
Minor Expenses	8.76	
		561.16
Balance		$481.32

KINGSLEY L. MARTIN, Treasurer.

INSTITUTE NOTES.

We have on several occasions called the attention of alumni to the souvenir album of the photogravure views of the interior, exterior and surroundings of the Institute buildings, prepared by Professor Bristol. In referring again to the matter we give the following notice of the work which appeared in the *London Chemical News*, and would state that copies of the album are still on sale at the treasurer's office.

"This work affords a twofold interest. On the one hand it gives us a brief view of the past history and the present condition of the Stevens Institute. On the other hand it is important as illustrating the vast progress of photographic art.

"The Stevens Institute owes its origin to private munificence. In 1867 the late Mr. E. A. Stevens bequeathed a suitable site and the sum of $150,000 for the erection of a building 'suitable for the uses of an institute of learning,' and also as an endowment for such institution, any sum not exceeding $500,000, which his executors might think necessary. The executors considered the whole of this sum necessary, and appropriated it accordingly. But, on both sides of the Atlantic, there is many a slip between the cup and the lip. The Government of the United States demanded, and seized upon, $45,000 as a 'collateral inheritance tax,' or, as we should say, legacy duty. Frequent attempts, we read, have been made to get this money returned, but without success—the more to be regretted, as the Government of the United States seems to be suffering from a plethora of wealth. This transaction reminds us of the old evil days when Waterton, returning home with his splendid collections in natural history, a large part of which were destined for public institutions, found himself compelled to pay a tax of 20 per cent. upon their supposed value.

"In 1870 Prof. H. Morton, Ph. D., at that time occupying the Chair of Chemistry in the University of Pennsylvania, was appointed president, and a charter of incorporation was duly secured.

"Chairs of physics, mathematics, chemistry, mechanical engineering, mechanical drawing, languages, and letters were at once instituted.

"Chairs of experimental mechanics and shop work, of marine engineering, of applied electricity, and of analytical chemistry, have been subsequently added.

"The photographs show the front of the Institute Building, the east side, the Institute Building looking east, the view through Castle Point Gateway, the rear of the Institute buildings, the general views from the Institute looking eastwards and south-eastwards, the Gateway of Castle Point, Castle Point Homestead, the Old Lecture Hall, the Library, Physical Laboratory, the Engineering Lecture-room, the rooms for drawing looking eastwards, the Chemical Laboratory, the workshop looking north-eastwards, east side of workshop, its west side, the foundry in basement, the Mechanical Department in the east basement, the Electrical Laboratory, the Electrical Lecture-room, the electrical gal-

lery in workshop, the boat engine of Colonel John Stevens (1804) the Stevens School, a preparatory institution, and the entrance to the Stevens School. Some of these illustrations, as photographs, call for especial notice.

"In the views of exteriors, we notice that while the foregrounds are perfectly clear and distinct, the distances have none of that heaviness so much complained of in photograph landscapes. This is particularly to be noticed in the view from the Institute looking to the east. Here the city and the open country in the background gradually fade away in the distance, as in nature. In the view to the southeast the distance is also happily rendered. The view of the workshop looking north-eastwards shows a novel and ingenious method of overcoming a difficulty which may often present itself in photographing interiors. We find here a row of windows facing the observer, or the camera, whilst between them and the eye come in a multitude of dark objects, full of details, wheels, driving bands, riggers, chains depending from the pulleys, etc., yet there is no blurring or obscurity. This result is obtained, as President Morton informs us, by calling in the flashlight to the assistance of daylight. The windows were first covered with dark screens, and the camera was used with a small stop. Long exposures were given, and the 'flashlight pistol' was used a number of times at the points which a previous negative had shown to be deficient in illumination. Then the lens was covered up, the screens were removed from the windows, and the camera was uncovered again for half a second. This useful expedient has been applied in some of the other interiors.

"Some of the rooms are illuminated with glow lamps, others with gas, and others seem to be fitted up for both these kinds of lighting.

"Judging from these illustrations, we should conclude that the Stevens Institute turns its attention much more to mechanical than to chemical technology. The chemical laboratory appears well organized for analysis and for research, but we see no workshops where the student may be initiated in the various branches of industrial chemistry. Perhaps if the Government of the United States sees its way to refund the $45,000 this deficiency may be supplied."

PROFESSOR COLEMAN SELLERS expects to start for home on February 7th. He is now in Rome, where he has gone on behalf of the Cataract Construction Company, to look into and report upon the remarkable electric light installation of Gauz & Co.

Professor Sellers has been detained in Europe much longer than he expected by the business of the Cataract Construction Company, which has involved extended conferences with the prominent engineers and electricians of England and the continent, but we shall expect to obtain from him an immense amount of useful information, especially on the electric transmission of power, which, he says, has been developed abroad much more than it has in this country.

THE INSTITUTE WAS REPRESENTED at the Richmond meeting of the American Society of Mechanical Engineers by Professors Denton and Jacobus.

Among the papers read at this meeting were the following:

By Professor Wood:

1. Some Properties of Ammonia. 2. Mechanical and Physical Properties of Sulphur Dioxide. 3. Theoretical Investigation of the Efficiency of Vapor Engines.

By Professor Denton:

1. Performance of a 75-Ton Refrigerating Machine of the Ammonia Compression Type. 2. Some Novel Experiments with a Lubricant.

By Professor Jacobus:

Experimental Determination of the Latent Heat of Ammonia and Sulphur Dioxide.

Professor Webb contributed a discussion of Professor Thurston's paper on Chimney Draught.

DR. STILLMAN attended the meeting of the American Chemical Society held at the University of Pennsylvania, Philadelphia, last month. He was elected curator of this society on December 5, 1890.

ABOUT TWENTY INSTITUTIONS of learning—universities and colleges—were recently endowed by the late Daniel B. Fayerweather, in amounts varying from $20,000 to $300,000. The Institute is not among the fortunate institutions receiving these bequests.

We believe that if it were not the general opinion that the Institute has sufficient funds to apply to its further development, whenever it should be deemed advisable to enlarge upon its present facilities, the beneficent gifts so frequently bestowed upon educational institutions might occasionally be shared by Stevens.

That the Institute is not in possession of funds sufficient for its immediate needs must, at least, be inferred from the limited accommodations in its chemical laboratory. This department is giving a most thorough course under serious disadvantages, and, when we consider the improvements that would be instituted if the necessary room were available, we cannot but wish that we could announce, in an early issue, the receipt of a gift for the establishment of a chemical laboratory, to be lodged in a separate building, with appointments that would enable the proposed changes to be carried out at once.

THE FACULTY has under consideration a plan for better regulating the examinations of conditioned students at the beginning of the college year. A more stringent system than the one heretofore enforced will probably be adopted.

PROFESSOR MAYER is now a resident of Hoboken. He and Mrs. Mayer occupy a flat at the corner of Tenth and Hudson Streets, and are very pleasantly located.

THE OIL PAINTING of Col. Edwin A. Stevens and the marble bust of Benjamin Franklin, the gifts of Mrs. E. A. Stevens to the Alumni Association, have been placed in the library. The painting occupies a position above the entrance at the east end of the library, and the bust has been placed at the west end of the room.

The portrait of the founder of the Institute is the first of a number of portraits which the Alumni Association contemplates presenting, and for which a special fund has been established.

THE DECEMBER NUMBER of the *Century Magazine* contains a beautiful Christmas poem by President Morton.

For upwards of two years Professor Morton has been pleasantly occupying leisure time, in preparing for publication a volume of poems, the greater part of which he wrote some thirty years ago. The volume is to be very fully illustrated, and the securing of the illustrations is the chief part of the preparation now going on, in which a number of artists are engaged.

President Morton's idea is to secure *illustrations which illustrate*, or, in other words, which are in sympathy with and carry out the ideas of the text. He has, therefore, put himself in close relations with those engaged upon the work so that the subjects to be treated and modes of treatment are fully discussed between author and artist, with results which appear to us to be eminently satisfactory. A large part of this collection of poems is of a humorous character, although the romantic and emotional has also a fair representation.

UPON THE OCCASION of the House-warming of the American Society of Mechanical Engineers, which occurred last November, at the Society's house, 12 West Thirty-first Street, New York City, the following Alumni of Stevens, members of the Society, accepted the invitation to attend, and participated in the enjoyable event, which was accompanied by the unveiling of an oil portrait of Alexander L. Holly, a gift to the Society by Mrs. Mary H. Bunker:

Wm. Kent, Gus C. Henning, Jas. M. Cremer, '76; Joseph Wetzler, Hosea Webster, '82; Jas. E. Sague, Frank Magee, Jr., '83; John A. Bensel, Henry L. Gantt, '84; Thos. G. Smith, '85; Henry A. Bang, '88, and Profs. Denton, Riesenberger and Jacobus.

INCLUDED IN THE VREELAND BEQUEST, recently received by the Institute, is a large pendulum clock about six feet in height. The year 1828 found upon it probably indicates its age. The clock has been set up in the physical laboratory, and is in running order.

PROFESSOR LEEDS read a paper on the "Chemical and Physical Changes Attendant upon the Sterilization of Milk," at the Philadelphia meeting of the American Chemical Society, held last month.

AMONG Charles Scribner's Sons' recent publications is one entitled "Electricity in Daily Life," which is a popular account of the applications of electricity to every-day uses. The book contains the article "Electricity in Lighting," contributed by President Morton to the August number, 1889, of *Scribner's Magazine*, and also the article by Joseph Wetzler, M. E., '82, on "The Electric Railway of To-day," which appeared in the April, 1890, number of the same magazine.

The work is meeting with a large sale, the first edition having been disposed of and the second edition being already issued.

PROFESSOR BRISTOL has been awarded the Medal of Superiority, by the American Institute, for his Recording Pressure Gauge. The Scott Legacy Medal and Premium, which were also awarded to Professor Bristol for his Gauge, by the city of Philadelphia, upon the recommendation of a committee appointed by the Franklin Institute, were forwarded several months ago. The medal bears the inscription : "The John Scott Medal. To the Most Deserving. To Wm. H. Bristol for his Pressure Indicator and Recorder. On Recommendation of the Franklin Institute, 1890."

WE HAVE NOTICED an item in many of our college exchanges stating that the faculty of the Stevens Institute had under consideration the lengthening of the course of study so as to make it a five instead of a four year course. The origin of this information is not known to us, but we can state authoritatively that no such change has been contemplated.

PROFESSOR JACOBUS has been appointed a member of a Sub-Committee of the Committee on Science and the Arts of the Franklin Institute, to examine and report upon the Pentz Boring and Milling Engine.

THE RIEHLE TESTING MACHINE.—The periodical test and readjustment of the Riehlé testing machine, by loading it with weights up to the limit usually required in the tests of specimens (20,000 pounds), has recently been completed. The greatest discrepancy recorded was 1⅙ per cent., which is no greater than that found in previous tests, notwithstanding that the machine has often been severely exercised in the many different tests for which it is used each year by the Department of Tests, and for instruction purposes during the Preliminary Term.

ON THE EVENING of January 7 a complimentary dinner was given to Chief Engineer Charles H. Loring, U. S. N. (retired), by his friends and fellow members of the Engineers' Club of New York City.

Chief Engineer Loring's services in the navy began with the year 1851, when he became Third Assistant Engineer; his promotion to the rank of Second and First Assistant Engineer followed in rapid succession. He was appointed Chief Engineer in 1861, and Chief of the Bureau of Steam Engineering in 1884, which position he filled with distinction until 1887. He was retired in December last after an active service of 40 years.

Professor Denton was one of the party of about 50 engineers who assembled on this occasion to honor the distinguished guest.

THE *American Journal of Science* for January, 1891, contains two articles by Professor Mayer, one on the "Illuminating power of Flat Petroleum Flames in Various Azimuths," and the other on the "Physical Properties of Hard Rubber or Vulcanite."

The first of these contains the results of measurements of the amount of light given out by two petroleum flames. One a flat flame of a Hitchcock lamp, and the other of an ordinary petroleum lamp. In both cases it was found that the flame gave out about 37 per cent. less light from its edge than from its flat surface.

In the second article are given the results of minute experiments upon vulcanite, a substance which is remarkable for its large co-efficient of ex-

pansion. The paper contains a sketch of the apparatus devised by Professor Mayer for measuring the co-efficient of expansion. The cubical expansion of vulcanite exceeds that of mercury, so that a thermometer with a bulb of vulcanite would have its scale inverted, as the mercury would fall with the rise of temperature.

PROFESSOR LEEDS was married to Miss Anne Griscom Webb, daughter of the late William Hewitt Webb, Secretary of the Pennsylvania Railroad, on Thursday, December 18, 1890.

The wedding took place in Philadelphia, at Old Christ Church, that famous old structure now surrounded by the whirl of business, but formerly the scene of the First Continental Congress, and of so many other familiar historic events.

The interesting old church, and its many associations so dear to Miss Webb and her family, one of whom had been its first bishop and another its late rector; the bride clad in the steel-colored gown in which her great-great-grandmother was married 150 years before; the wedding ring which had been used by both grandmother and great-grandmother; the old chimes that had not sounded for a wedding for so many years—all these served to make the ceremony one of rare interest.

The church was filled with friends of the happy couple. The Rev. William Walter Webb, brother-in-law of the bride, officiated, assisted by Dr. J. Lewis Parks, of Middletown, Conn.

The bridesmaids were Miss Helen Carpenter, Miss Harriet D. Schaffer, Miss Bessie Ripley and Miss Edith Ripley, of Brooklyn; Miss Evelyn Dorr, Buffalo; Miss Mary Gayer, Charleston, S. C.; Miss Nora Davis and Miss Esther Ashton. Mr. Frank Bond, brother-in-law of Judge Reed, was the best man, and the ushers were Mr. George S. Perkins and Mr. Alexander Dow, Mr. Edward Carpenter, Mr. Charles Davis, Dr. Thomas Rushton, Mr. William B. Gilpin and Mr. M. C. Skull.

After the ceremony the near relatives and friends repaired to "Roadside," Germantown, the home of the bride's mother, where a reception was attended by many distinguished guests. The reception over, the married pair departed on their wedding tour.

There were many handsome and costly presents, amongst others a token from the class of '91, as an expression of their great pleasure in an event of so much importance to the Professor, whom every member of the class has always held in high esteem.

AT A MEETING of the Athletic Association, on January 13, 1891, the following officers were elected: President, Kingsley L. Martin, '92; Vice-President, Harold E. Griswold, '93; Secretary, A. E. Merkel, '93; Treasurer, H. F. Cuntz, '93; for the remainder of the Executive Board, N. S. Hill, '92; Wm. E. Strong, '92; Geo. B. Fielder, '94.

Life appears this year in a new and attractive form. The number of pages has been increased, and a handsome cover combining the college colors has been added. The paper is filling a valuable place in undergraduate affairs and the present Board of Editors deserve credit for their successful management.

THE COLLEGE PIN.—The committee appointed by the different classes to select a college pin has completed its labors. The design chosen is a diamond-shaped, gold pin, with a raised centre, enameled in the college colors, cardinal and gray. These are separated by a fine gold band, running parallel to the sides of the pin from the middle of the upper to the middle of the lower side. The name "Stevens" appears horizontally across the colors in gold letters. A fine gold rope surrounds both the central part and the outer rim, and the whole effect is very neat and tasty. The pin is somewhat narrower one way than the other, and is worn so that the longest diameter is horizontal.

This pin has been generally adopted by the undergraduates, and they hope it will be officially recognized by the alumni association. This custom, now starting under such favorable auspices, will probably take its place among the permanent institutions at Stevens.

THE *Link* of 1891 will be published in a form very similar to that of last year. The editors are: F. H. McGahie, Beta Theta Pi; W. B. Everitt, Chi Psi; Wm. E. Strong, Chi Phi; W. O. Ludlow, Delta Tau Delta; Geo. L. Manning, Sigma Chi; D. W. Blake, Theta Xi, and W. B. Powell, neutral. Manning is a member of '91 and Blake of '93, their fraternities having no members in '92.

ON NOVEMBER 12 the Stevens Social Society elected the following officers: President, J. Arnold Norcross, '91; Vice-President, W. C. Cuntz, '92; Secretary, Geo. S. Perkins, '91; Treasurer, E. S. Moffet, '93.

TWO INTERESTING papers were read at the meeting of the Stevens Engineering Society, held November 14, 1890. The first, "Marine Governors and the Causes of their Failure," was by Johann M. Hansen, and is published in this issue; the second, by J. Alfred Dixon, was upon "The Manufacture of Gas from Oil."

At the meeting held January 16, 1891, papers were read by Messrs. H. W. Smith and Griswold Knox. Mr. Smith's paper was on "The Manufacture of Hemp Rope," and Mr. Knox's on "The New Fire-boat, 'New Yorker'." Both papers were illustrated.

STUDENTS ARE much pleased that the periodicals are again placed on the library tables. It should, however, be remembered that this is done upon the condition that the papers will not be unnecessarily mutilated. We must infer from the appearance of some of the papers that not enough care is being exercised in handling them.

A CHESS CLUB has been organized, with the following members: De La Rosa, Lorsch, '91; Atkins, '92; Braine, Wall, '93; Buffett, Hall, Jones, Fridenberg, Oppermann, Coleman, Corbin, Angell, Wendt, '94.

Permanent officers will soon be elected.

Room for the chessmen, books, etc., has been secured in the library, and meetings are to be held there every Friday afternoon. All those in the Institute who play chess are invited to attend.

WANTED.—Nos. 7 and 9, 1885, and No. 1, 1886, of the INDICATOR, to complete a set.

INSTITUTE PERSONALS.

'76.

Gus C. Henning has established an office, as Consulting Engineer, at 726 Temple Court, New York City.

'77.

John Rapelje has left Elkhorn, Va.; his address is now Hopewell Junction, Dutchess County, New York. About the middle of November he started on a six weeks' trip to the West.

'78.

A. W. Gibbs is Superintendent of Motive Power of the Central Railroad of Georgia, and is located at Savannah, Ga.

Oscar Antz was appointed Master Mechanic of Savannah shops of the Central Railroad and Banking Company of Georgia, Savannah, Ga., to succeed F. H. McGee, transferred. The appointment was made December 1, 1890.

Edward P. Thompson read a paper on "How to make Great Electrical Inventions" before the New York Electrical Society on December 10, 1890. An abstract of the paper appeared in *The Electrical Engineer* of December 17.

From the *National Car and Locomotive Builder* of January, 1891, we extract the following: "During last year the Cumberland and Pennsylvania R. R. Co., which are the successors of the Mount Savage Locomotive Works Co., built in their shops at Mount Savage. Md., two consolidation locomotives with cylinders 20x24 inches, and having a total weight of 103,000 pounds on the drivers. The work was done under the supervision of Mr. Henry T. Brück, master of machinery, who is noted as a particularly capable and systematic shop manager."

'80.

Durand Woodman has removed his laboratory to No. 80 Beaver Street and 127 Pearl Street, New York City.

He has been elected a member of the Berlin Chemical Society, and at the meeting of the American Chemical Society was elected Recording Secretary for the ensuing year. At the Philadelphia meeting of the American Chemical Society held last month, Mr. Woodman read a paper on "The Necessity for the Systematic Inspection of Wells in Cities and Towns."

'81.

Jas. B. Ladd, who has been engaged for several years as engineer of the Pennsylvania Steel Co., in the constructing of the new works of that company at Sparrow Point, Md., has resigned his position on account of ill health. His withdrawal is sincerely regretted by the company, but Mr. Ladd is forced to believe that a recovery of health necessitates a change of residence.

He sailed for Europe on the "Germanic" on the 28th ult. for a six months' absence. On his return he will be with Robert Poole & Son Co., Baltimore.

Referring to the occasion of the recent Alumni meeting, he writes: "I am feeling miserable or I should be at the meeting to-night. I intend spending most of my time while abroad along the Mediteranean, and hope to return free of malaria."

'83.

JAMES E. SAGUE was married to Miss Jeannette Kenyon, Thursday, October 30, 1890.

'84.

WM. H. PIERCE is connected with the Edison General Electric Co., Edison Building, Broad Street, New York City.

FRANK VAN VLECK presented a paper on "Light Cable Road Construction," at the Richmond meeting of the American Society of Mechanical Engineers, held in November last. The paper has been extensively reprinted by the engineering press of the country.

GEO. F. SANDT is one of the assistant engineers in the General Edison Electric Co., at the New York office.

'85.

ARTHUR G. GLASGOW read a paper on "The Practical Efficiency of an Illuminating Water Gas Setting," at the meeting of the American Gas Light Association, held at Savannah, Ga., in October, 1890.

The paper is published in full in the *American Gas Light Journal* of December 8, 1890. Commenting editorially upon the paper this journal states: "Its lines teem with evidence, readily enough obtainable at a glance, that Mr. Glasgow labored long and studiously over the task assigned him, and he is to be congratulated on the striking way in which the compilation of his studies is set out.

"The reader cannot fail to admire the conscientious way in which Mr. Glasgow has conducted his work, and it is quite safe to predict that he will be heard from later on, and prominently, in connection with his chosen profession."

ROLLIN NORRIS and JOHN M. RUSBY were also present at the meeting and took part in the discussion of Mr. Glasgow's paper.

PROFESSOR THURSTON has been elected "Member Correspondent" of the "Superior School l'Industrie Nationale," at Paris, in recognition of his services to science in translating into English the works of the elder Sadi Carnot, the pioneer of the science of thermodynamics.

At the Richmond meeting of the Amer. Soc. of Mech. Engineers Professor Thurston presented two papers—"Authorities on the Steam Jacket," and "Chimney Draught—Facts and Theories."

EDWIN BURHORN is the Draughtsman for the Link Belt Engineering Co., Nicetown, Pa.

W. HARVIE WADE has been draughting for E. D. Leavitt, M. E., at Cambridgeport, Mass., for six months. He is now residing at 219 Degraw Street, Brooklyn, N. Y.

'86.

W. S. CHESTER has given special attention to perfecting an electric motor to be applied in the blowing of church organs. How well he has succeeded in solving the problem may be judged from the following extracts from an account, in the New York *Times* of December 16, of the working of these motors in several of the larger churches in New York City.

"It is due to the ingenuity and energy of one of the best known organists of this city, Mr. W. S. Chester of St. George's Episcopal Church, that this particular field of electrical application has not only been made possible, but exploited to its present and rapidly growing dimensions.

"The ease with which the electrical motor was installed and connected to the street wires, the smoothness of its operations, without heat, noise or odor of any kind, requiring scarcely any attention, the very moderate outlay required for installing and operating it, proved at once its great superiority over all the other methods that had been employed for blowing purposes."

These motors have already been introduced in many of the churches of New York City and other places.

JAMES S. MERRITT was married to Miss Gertrude R. Morris on January 28, 1891, at the Calvary Presbyterian Church, Locust Street, Philadelphia, Pa.

J. LESTER WOODBRIDGE delivered a lecture upon "Some Interesting Phenomena Observed in the Operation of Electric Railways," at a meeting of the Physics Department of the Brooklyn Institute, held in October.

The firm of Woodbridge & Turner are engaged in extensive railway construction work. During the past month they have started the construction of two roads, one at Quincy, Ill., and the other at Amsterdam, N. Y.

THE FIELD ENGINEERING COMPANY, which was organized by C. J. Field and E. F. White, has now the largest staff of engineers of any firm in their line. Their work is so organized that each member of the company has his specialties. Of the force of twelve engineers four are Stevens men. The company was organized in January, 1890, and, although only a year old, has been remarkably successful. It makes a specialty of central stations and electric railways. During the past year the company has completed four large contracts, and has now in hand the two largest contracts ever let in the electric railway line. They consist of the complete equipment of 200 miles of line, including stations, steam and electric plants, line work and conduits. These are to be made model plants in every respect.

E. F. BIRDSALL and L. W. SERRELL have established themselves at 115 Broadway, New York City, under the name of "B. & S. Electric Equipment Company." The firm makes a specialty of electric railway supplies.

E. F. WHITE, Vice-President of the Field Engineering Company, is in Europe on business. His two months' stay will be spent visiting Germany, Italy, France and England for the purpose of examining into the latest construction work in electric engineering in these countries.

E. J. COOK resigned the position of General Superintendent of the Brooklyn Edison Company on the 1st of last October, to accept the position of Constructing Engineer in the Field Engineering Company.

E. D. SELF returned, a short time ago, from Central America and Mexico, where he has been for nearly a year for the exporting firm of Coombs, Crosby & Eddy, 78 South Street, New York, with which he is still connected.

'87.

ALFRED H. SCHLESINGER is associated with Chas. W. Thomas, '84, as successor to J. H. Pendleton, the firm's name being Thomas & Schlesinger, with offices at 119 and 121 Nassau Street, New York City. The firm is prepared to execute work in the line of mechanical and hydraulic engineering.

The Electrical Engineer of December 10, 1890, contains a table for calculating dynamo and motor windings, computed by Lemuel W. Serrell. The table, which has been prepared on the ampere-foot basis, will have considerable value for manufacturers of dynamos.

FRITZ UHLENHAUT, who is Assistant Engineer in the Field Engineering Company, has had charge, during the past year, of the construction work of this company at Winston, N. C., and at Boston, and is now engaged on special work at the New York office.

'88.

BURTON P. HALL has been connected with the Hall Steam Power Company, 221 Centre Street, New York City, since last March, when he resigned his position with the Welsbach Company.

D. H. LOPEZ is Assistant Superintendent of the Coosaw Mining Company, Sea Island Chemical Company, and Oak Point Mines Company, at Coosaw, S. C.; he accepted this position in December, 1889.

ARTHUR L. SHREVE was elected a junior member of the American Society of Civil Engineers on November 5, 1890. He is still located in Baltimore, Md., as Assistant Engineer, in the City Commissioner's Department, and is engaged upon the extensive system of sewerage work building in the city of Baltimore.

WM. B. YERRANCE has been appointed Assistant Professor of Civil Engineering in the University of the City of New York.

T. A. VAN DER WILLIGEN is now located with the Grand Rapids Gas Company, Grand Rapids, Mich.

'89.

ROBERT G. SMITH has had a severe attack of pleurisy, which compelled him to suspend his studies at Worcester Academy and to return to his home at Plainfield, N. J. He resumed his course in the classics after

the Christmas holidays, and expects to be prepared to enter Brown University next September. He enjoys the classics even more than Science and Mathematics.

GEO. ARMOUR has left the employ of the U. S. Aluminum Metal Company, at Boonton, N. J. His present address is 121 Madison Avenue, New York City.

ROBT. C. OLIPHANT is draughting for the Link-Belt Engineering Company, Nicetown, Pa.

'90.

LUIS R. MENDOZA has returned from Mexico, and has taken up his residence at 333 Willow Avenue, Hoboken.

W. W. KISSAM, HENRY S. LOUD, and G. A. TRUBE, are in the employ of the South Chicago Iron Works, South Chicago, Ill.

J. F. HAWORTH is in the employ of the Pittsburg and Birmingham Traction Company, Thirtieth and Carson Streets, Pittsburg, Pa.

W. F. LAWRENCE is with the Natural Gas Fuel Company, 74 Cortlandt Street, New York City.

SHIRK BOYER has been in the employ of the Sloss Iron and Steel Company, Birmingham, Ala., since November 1, 1890.

JOHN S. DEHART, JR., is now with Henry Warden, Germantown, Junction, Philadelphia, Pa.

WM. N. CARLTON, has left the Dodge Coal Storage Company. His present address is Elizabeth, N. J.

E. W. FRAZAR is in the laboratory of the United States Mine Signal Manufacturing and Supply Company, 915 Ridge Avenue, Philadelphia, Pa., as assistant to Thos. Shaw, M. E., President and General Manager.

E. H. PEABODY, is in the employ of the Eastern Electric Company, and is located at Dover, N. J.

'92.

J. H. MURRAY was married on Christmas Eve.

'93.

MORS O. SLOCUM, a graduate of Rochester University, Rochester, New York, joined '93 at the beginning of the winter term.

J. C. TOALE has left the Institute to take charge of his father's mill at Charleston, S. C. His class regretted very much to lose him.

'94.

OLMSTEAD has been elected class historian in place of Hodgman, resigned.

LEMUEL WARNER, Lehigh University '93, has joined the freshman class. The class now numbers 61 members.

A GYMNASIUM CLASS has been organized. The members will devote two afternoons in each week to practice in the gymnasium.

MAYNARD AND COYNE played on the foot-ball team of the Orange Athletic Club, in their final game with the Crescents in Brooklyn.

BOOK NOTICES.

ACCESSIONS TO INSTITUTE LIBRARY, JULY 1 TO DECEMBER 31, 1890.

By Purchase:

Annales de Chimie et de Physique. Third Series, Vols. 16, 21, 31, 32. 33. 1846 and 1851.

Index to Transactions of the Royal Society of Edinburgh, 1783-1888. London: Niell & Co.

The Century Dictionary. Vols. III. and IV. New York: Century Co.

Moulder and Founder. Overman. 1873. Philadelphia: Baird.

Manual for Railroad Engineers. Geo. L. Vose, 1875. Boston: See & Shepard.

Journal of Franklin Institute. 3d Series, Vols. 97, 98, 99.

London Engineer. Vols. 68 and 69.

Scientific American. Vol. 62.

Scientific American Supplement. Vol. 29.

London Engineering. Vols. 48, 49.

London Electrician. Vol. 24.

Annales de Chimie et de Physique. Vols. 17, 18, 19 and 20.

Proceedings of the Royal Society. Vols. 44, 45, 46.

Chemie des Steinkohlentheers. Farbstoffe. Vol. 2, 1887-90. 1368 pp.

American Journal of Art and Science. Vols. 38 and 39.

Comptes Rendus. Vols. 107, 108, 109.

Specifications and Drawings of Patents: June to November, 1889. 12 Vols.

Nature. Vols. 40, 41.

Incandescent Wiring Hand Book, 1890. By F. B. Badt. 72 pp.

Exercises in Electric and Magnetic Measurement. By R. E. Day. London: Longmann, Greene & Co., 1889. 189 pp.

Practical Notes for Electrical Students. By A. E. Kennedy and H. D. Wilkensen, 1890. New York: E. & F. N. Spon. 308 pp.

Chemical News. Vols. 60 and 61.

The Richards Steam Engine Indicator. By Chas. T. Porter. New York: E. & F. N. Spon, 1888.

The Steam Engine. By D. K. Clark. 4 Vols. New York: Blackie & Son, 1890.

Contributed:

By Prof. Morton: *Proceedings Society of Gas Lighting,* 1890. Pp. 132.

Elliptic Functions. By A. L. Baker. New York: John Wiley & Sons. Pp. 118.

Electricity in Daily Life. 1890. New York: Scribner's Sons. Pp. 288.

By Prof. Denton: *Transactions of the American Institute of Electrical Engineers.* Vol. V., No. 1, 1887; Nos. 4, 8, 9, 10, 11, 12, 1888; Vol. VI., Nos. 2, 4, 5, 8, 9, 11, 12, 1889; Vol. VII., Nos. 5, 6, 7, 1890.

By Prof. Stillman: *Lessons in Elementary Chemistry.* By Roscoe. New York: MacMillan & Co. . Pp. 459.

By F. E. Idell: *Scientific American.* Vols. VII., IX., X., XI.

Triple Expansion Engines. By Prof. Osborne Reynolds. Edited by F. E. Idell. New York: Scientific Series. D. Van Nostrand Co., 1890.

By J. J. Kunstadter: *Report of Experiments with Kunstadter's System of Combined Rudder and Swivelling Screw as Applied to U. S. Screw Steamer Nina.*

By Jas. Bischop: *Bureau of Statistics of New Jersey.* Camden: F. F. Patterson, 1889.

By Thos. Siddon: *Economic Conditions of the Manufactures of Birmingham, Ala.*

By A. P. Boller: *The Thames River Bridge.* By A. P. Boller, Chief Engineer. New York: Engineering Press, 1890.

By The Frick Co.: *Eclipse Refrigerating Machines.*

By John Wiley & Sons: *Valve Gears.* By Spangler. New York: Jno. Wiley & Sons.

Mechanics of Engineering and of Machinery. By Weisbach & Hermann—Translated by Klein. 2 vols. New York: John Wiley & Sons.

Friction and Lost Work in Machinery. By R. H. Thurston. New York: John Wiley & Sons. Pp. 365.

By British Institution of Civil Engineers: *Minutes of Proceedings of the Institute of Civil Engineers.* Vols. C., CI., CII., 1890.

By U. S. Bureau of Education: *The History of Federal State Aid to Higher Education in the U. S.* By Frank W. Blackmar, Ph.D.

English Eskimo and Eskimo English Vocabularies. E. R. Wells, Jr., and Jno. W. Kelly.

History of Education in Alabama, 1702–1889. Willis G. Clark.

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By Association of Engineering Societies: *Journal of the Association,* Vol. IX., No. 4, 1890. Chicago.

By Smithsonian Institution: *Smithsonian Contribution to Knowledge. Memoirs et Comptes Rendus de la Society Royal de Cavado,* 1889. Montreal. Dawson Smithsonian Miscellaneous Collection.

By H. G. Reynolds, Secretary: *Twenty-eighth Annual Report of the Secretary of State Board of Agriculture of State of Michigan.* June 1, 1888, to June 30, 1889.

By Board of Education of Jersey City: *Twenty-second Annual Report of Board of Education of Jersey City*, for the year ending Nov. 30, 1889.

By U. S. Department of Agriculture: *The Work of the Agricultural Experiment Stations in the U. S.*

List of Botanists of the Agricultural Experiment Station Record. Vol. I., No. 5 and 6; Vol. II., No. 1.

Proceedings of the Third Annual Convention of the Association of American Agricultural Colleges and Experiment Stations, held at Washington, D. C., November 12 and 15, 1889.

By U. S. Ordnance Department: *Notes on the Construction of Ordnonce*, Nos. 20, 21, 22, 23, 24, 31, 45, 46, 47, 48, 50, Government Printing Office, Washington, D. C.

By U. S. Navy Department: *A New Theory of Jupiter and Saturn.* by Geo. H. Hill, 1890.

Washington Observations, 1884.

The American Ephemeris and Nautical Almanac.

Astronomical Papers. Vol. 2, No. 1.

By U. S. War Department: *Report of the Chief Signal Officer*, 1889.

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Report of the Consuls of the United States, 1890.

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By the U. S. Interior Department: *U. S. Geological Survey; Mineral Resources of the United States.* By David T. Day, 1888.

Geological Survey of New Jersey; New Brunswick, 1890; *Camden*, 1888.

Final Report of the New Jersey State Geologist. Trenton, N. J.

Den Norske Nordhaus Expedition, 1876–1878. D. C. Danielesen. Christiana, Groudahl & Sons.

Annual Statistics of Manufactures and Report of Bureau of Statistics of Labor. Boston: Wright & Potter Printing Co.

THE STEVENS INDICATOR.

VOL. VIII. APRIL, 1891. NO. 2.

COURSE OF LECTURES IN THE DEPARTMENT OF ENGINEERING PRACTICE.

BY PROF. COLEMAN SELLERS, E. D.

I.—DRAWING ROOM PRACTICE.—ABSTRACT.

THE lectures expected from me to fill the want expressed by the name of this chair—that of Engineering Practice—calls for practice more than theory, and will be the most useful in attracting your attention to the way you can apply the instruction you have received in school, from your Freshman year to the final course that is to end your work in the school, and to usher you into the active practice of the profession you have chosen.

Mechanical engineering, as a profession based on scientific methods, has its whole life coincident with the professional career of men yet workers. The names highest on the roll of fame belong, in many cases, to men who have not had your advantages. Many very able engineers suffer, too, for the want of what you may have considered the drudgery of your work in school.

Mathematics, as taught in the schools where such men as Oliver Evans, at the beginning of this century, and many engineers now living received their early instruction, was limited to the rules of arithmetic, with too little knowledge of algebra to be worth the name, and very little of the higher mathematics. The theories of thermo-dynamics did not guide the men who brought the steam engine to its perfection. Written thermo-dynamics is the study of the steam engine as worked out tentatively.

There are minds naturally fitted to master mathematics, while others find such study irksome. It is, however, noteworthy that

mechanical engineers of great mathematical ability have made, in constructive engineering, as great mistakes as those who lay no claim to such knowledge. The inventive faculty, so needful to an engineer, grows with practice and is susceptible of cultivation. With what has been accomplished by educated, as well as uneducated minds, each year calls for a greater talent to improve on what has been done, or to fill new wants.

If you inquire into the life history of men who, with little opportunity, have achieved distinction as engineers, you will find that to natural ability has been added the result of deep thought, close application to business, and memory well stored with observed facts. Such men have been students all their lives, and they have had to depend upon and knew how to select others to help them. Thus, an engineer lacking the ability to work in the way you have been taught to labor, usually employs those who have been educated, checking the results of their figures and their ideas by his own practical knowledge.

Presuming you may be sought for in such work, you can be the more useful and fill a broader plane of utility if you are made familiar with some of the customs and usages of the existing engineering establishments where men of all capacities are employed, and where it behooves those who would know how to manage to familiarize themselves with shop customs. If, too, you are employed to serve, and not to manage, this fore-knowledge will enable you to appreciate customs that may seem antagonistic to what you have learned in school.

The drawing room is the source of inspiration in the workshop. Manufacturing establishments exist and thrive with very little talent in the drawing room; but in all such cut-and-try places progress is slow, the products not what they should be, and mistakes so very common as to be the rule, and not the exception.

During the yast year I have had an opportunity to watch some new mechanical growths that have given me much food for thought.

We are just now entering upon an era in engineering in which new modes of transmission are being worked out, and the leading force in this is electricity. Everywhere new establishments are springing up for the production of electrical appliances, and the school men are in demand. I have seen instances where large enterprises have been entrusted to young men of marked ability and

little practical experience. In some cases these young men are able, by their education mainly, to take places that older and more experienced men could not manage; but in too many of these places youth and inexperience is shown in their designs, and more strikingly in the shop systems employed. These faults will cure themselves with time, and in the bustle of life youth matures and experience comes only with time.

If any of you find your way into the machine shop, you are most likely to find administrative ability that which will serve you the best.

Draughtsmen taught in the shop, without any previous school instruction, begin as pupils and are put to make tracings, blue-printing and the like, and as they become familiar with the use of instruments, in tracing drawings made by others, they can then be trusted to make forging drawings or the card drawings in which individual pieces of other drawings, separate pieces of the machine that is being designed, are figured each by itself for the department in which it is to be used. They are expected to learn by observation, and not by any system of instruction.

At the bottom, or at the top, whichever way you may be pleased to consider the growth, lies a full knowledge on the part of the draughtsman of what is the shop system of the establishment in which he is employed. He must know, too, what is the scope or capacity of the tools, both machine tools and the minor tools, that he may adapt his work to the capacity of the machines to be used in making what he is designing.

He must know just how the work is to be executed; and the wise designer spares no expense or care in the drawing-room. By careful forethought as to mode of construction, the drawings go into the pattern shop with full information as to how the cast-iron parts will be molded, and with all draught allowances provided for. If the patterns are to make their own core, the allowance for draught may be made to subserve beauty of form.

Let us suppose a design calls for a bed plate upon which the parts of the machine rest; due care will bring the castings from the foundry into the machine-shop so proportioned that, regardless of unequal shrinkage in the castings, there will be no unsightly overhanging edges to be chipped or dressed off at more or less cost and, in the end, want of graceful outline.

The early designers copied in iron what had been made in wood by the older millwrights. Shapes well enough in architecture

are unfitted for machinery. Sir Joseph Whitworth was one of the first designers of machinery who strove for simplicity and fitness for use, resulting, as well considered simplicity does, in beauty of form.

Let me impress on you the importance of rigid adherence to shop sizes, and explain the meaning. When you come to buy on the market what is required, you will find that bar iron, bar steel or metal shapes, bolts, nuts and screws of all kinds, wire, hardware, etc., are made in gradation of sizes called merchant sizes. Uniformity in merchant sizes leads to cheapness and convenience.

Each size from the smallest to the largest in all matter in the market is fixed by the laws of trade and the wants of the community. In the shop every size, nominal or actual, requires many tools to maintain it. If you examine a well-fitted tool room for the article known as one-inch size, if you will make a list of some of the tools required for that size, you will be astonished at the total number: from 20 to 40 or more to each size.

This collection must be repeated for each step in the shop series of sizes, many being exact to size and others merely nominal. Thus, the tap for one-inch gas pipe is the tap that will cut the screw thread in a fitting to go tightly on an inch-pipe. The one-inch pipe is not one-inch diameter either on the outside or on the inside. When wrought-iron gas pipes were introduced as an article of trade, they were made as nearly as might be of the named bore, and the thickness of "scelp" used, determined the outside diameter and fixed the thread that should be used in coupling. After a time thinner iron came to be used as "scelp," and to make such thinner pipe interchangeable with the thick ones, the outside diameter was maintained and the bore made larger. This one example is enough to show you how trade convenience and constructive convenience go together and, in time, create trade names that cannot be verified by the name of the size as given. Very much as with words and their etymology—*vide*—"cheval" from "equus," no doubt, but so sadly altered by the way.*

Shafting for transmission of motion is made of bar iron of merchant size reduced in every case one-sixteenth of an inch in diameter, and the finished shafts are, in every case, less by that amount than the name by which they are sold, namely, one-sixteenth of an inch less than their nominal size. A 3-inch shaft measures, as

*"John Bull, Jr.," by Max O'Rell.

turned out by all the leading shops, $2\frac{15}{16}$ inch diameter, and so for all other sizes. For exactness of definition, such anomalous sizes are called from their use "shafting-size."

Our metrology lends itself to a good shop system better than does the metrical system in use in France and Germany. We say, for instance, that the shop sizes in use are by one-sixteenth up to one inch, or to one and one-half inch, as the case may be, and to 3 inches by one-eighth inch, from three to four by one-fourth inch, and by one-half inch above that size. Some such system of shop sizes is easily carried in mind, which is not the case when the millimeter is the unit of measure, when the shop series advance, not by one or by two millimeters, but by one, two or three in alternation, as they agree with the sizes nearest to our inch series, for the reason that the Whitworth system of screw threads, based on the inch and its subdivisions, is in use outside of the United States, and merchant bar iron is to the inch metrology.

The shop sizes in common use in France and Germany must be memorized as they exist, and often they are not expressive of the actual size used. Thus an inch tap is called 25 millimeter, but yet it will measure 25.4, perhaps.

Over thirty-five years ago I so far advocated the introduction of the metric system into the machine shop as to help to its introduction entirely into one large department of the works I was connected with, and became familiar with the system so far as to feel that it was part of my unconscious mental action, but its faults were shown so strongly in contrast with the inch series that I came to be an active opponent to its forced introduction where it was not convenient in use. I do, however, strongly advocate its use when and where it is best adapted, as in the chemical laboratory, for instance, and in the new branches of science, as in electrical measurements. When you are tempted to consider the so-called advantages of a decimal system of linear measure, I would have you think well before you commit yourself against the customs that obtain with English-speaking nations, holding to that which is the most convenient and useful, not only to you, but to others.

"Mechanical drawing is an embodiment of, for the most part, original thought, combining technical knowledge and manual training. The imagination must be on the alert the whole time." Sir William Thomson's rule is a good one, that when one sets to work to design anything, he must at first contemplate ideal con-

ditions, with the intent to reach the most perfect thing possible; then to modify the design so as to comply with practical considerations.

Let any given subject be presented to the designer, calling for invention. He must, before proceeding to the work of designing, inform himself thoroughly as to the nature of the matter he has to deal with, as well as of the known methods of operating upon the matter.

All machines are contrived to do some sort of useful work. The work to be done must be well understood at the beginning. This is admirably illustrated in the invention of machine tools, and special machines of all kinds. The very slow progress made in some trades towards the use of efficient labor-saving machines is strikingly illustrated in the coining of money and striking of medals. In the case of gold and silver coin, the metals used are ductile and malleable and of sufficiently uniform quality to promise uniform results with uniformity of treatment. Such, however, does not obtain in practice. There is room and much room for improvement in the machinery used by the Governments of the two great English-speaking nations, in the machinery of their mints. Were these manufacturing establishments in the hands of individuals interested in cheapening and improving their processes, inventive faculty and technical knowledge would be brought into play to perfect the machinery required to do what looks like very simple work. Let us select one minting process.

The medals struck by the United States mint are made in a fly-press, operated by a quick pitch steel screw, 6 inches in diameter, working in a gun-metal or bronze nut. A long cross bar or wrench at the head of the screw is loaded with heavy ball weights at its outer ends, and the press is worked by two men, one at each weighted end of the lever, who, running around to give an impetus to the weights which presently are brought up suddenly by the upper die striking the blank medal, when the men must spring to one side to avoid the recoil of the great weights which fly back with force and are then deliberately run back until the screw is up ready for the next stroke. Here we have a crude machine, differing only in perfection of workmanship and size from the machines used away back in the centuries.

Let us invent a machine to take its place as an illustration of how useful machines are contrived. Our new machine must have

top and bottom dies to produce the face and reverse of the medal, and the blank must be held in a collar or bounding ring of steel to form the edge. Into this ring the medal will be expanded and from which it must be released when the compression has been accomplished.

The treatment of the metal thus compressed belongs to the class of operations grouped under the head of the flow of solids. Gold, silver and copper, and most metals, except lead, cannot be made to flow continuously without a given amount of power per square unit, as the metal hardens by compression, and can be made to fill the die perfectly with the least strain, by a process of annealing between each of the successive compressions required to bring up the metals in high relief. The slight relief on our coins is about the limit of what can be done at one stroke of the dies.

Why should we retain this old fly-press when similar operations in the arts are accomplished by simple means?

The hydraulic press of Brama, powerful but slow, has grown into the quick working hydraulic riveting machine and the modern forging press; machines for doing just what is wanted in this case. A hydraulic press with two rams, one above and one below, supplied from an adjustable accumulator which can be loaded to any required pressure per square inch. Experiments will fix the pressure required for each compression, and calculation will enable us to judge just how much pressure we can give without bursting the steel collar. The strength of each part of such a machine can be calculated by well-known rules, and the machine can be operated by one man who places the blanks between the dies, and the labor of the two men who operate the press will be dispensed with.

I have proposed two cylinders; one you will understand is for the compression of the medal, the other below and acting upwards, is to raise the lower die through the collar and so reject the tightly fitting medal. The collar being held down by projection from the housing, may be slightly taper in its bore, so that if the upper opening of the collar is rather smaller than the place where the medal is expanded, the *medal* will be slightly reduced in diameter in being rejected and so be able to enter, after being annealed, the same collar by its larger end for each minting.

Some years ago I proposed to the Superintendent of the Mint in Philadelphia such a press, and he permitted us to strike a medal

in a hydraulic wheel press capable of 150 tons pressure. He found the operation satisfactory until the collar, unprotected by a wrought iron sleeve, burst and a bit of flying metal cut him on the forehead. This ended the matter, or rather no more was done. And in one view of the case, why should he do more? The new machine would have done away with two low-pay men whose votes were just as good as if they had more wages.

This outline of a possible minting press for large medals is sufficient for any of you to work out all the detail of such a machine; but your design should be made with the mind well informed as to just what machine tools you have available for each part of the machine. A good rule to bear in mind is that in constructions of this kind the chief part of the machine may be made in one piece, and be the better for not having any multiplicity of joints, provided the one piece can be handled and machine tooled. What may do well in this case by a monolithic treatment does not hold good in all cases. A double upright hammer of the Morrison type, with the cylinder bolted between two wide spreading uprights, was a construction that was continued for years, until, such uprights breaking in use, the idea was forced upon designers that more parts with wood layers between some of them would be rigid enough, but its elasticity would make it more lasting. The argument was: as the uprights always break at about the same place, let us part them at that place and begin with a broken structure that can be held by sufficiently elastic fastenings.

Well placed elasticity is called for in marine design. Armor plates held by ordinary bolts or rivets were found, say in the turrets of monitors, to deal death to those behind the defence. The bolt or rivet heads fly off on a ball striking the outside. This evil is cured, as it is cured in other cases when bolts give way under sudden shock, by reducing the whole body of the bolt to less than the bottom diameter of the threaded end. When a bolt is not so reduced, its weakest point is the bottom of the thread next to the body of the bolt, but if this threaded end is larger and stronger than the whole body of the bolt, the threaded part will be the strongest part and the long weaker body will be elastic enough to yield at each shock without breaking, throwing the strain suddenly on the weak section at the root of the thread of the screw.

I give these few hints as to how the engineer's mind must be led to dwell on cause and effect.

We are entering upon an age of steel. I will not say much about alumina, for it, as a cheap metal, is too new; but steel of to-day is something we can know more about. When I began to use steel I bought such as was in the market; tool steel in bars, or merchant rounds; bars of blister steel for springs of locomotives, and in each and every case I had steel of this or that maker's name, and beyond the name of the maker I knew nothing. Steel making was carried on as a trade secret until the time came when the chemists began to take existing steel to pieces by analysis, and then by synthesis tried to build up similar structures. The empirical trade secret of steel soon broke down before the light of science. Now we do know what can be done with steel, and we know how to select steel for the purpose it has to fulfill in constructive design. If you do not know this yourself you can know what you want, and by expressing what you do want clearly the steel maker can give you the qualities required.

Drawings should in all cases be marked with the metal to be used in construction, and this information must come from the drawing room.

Steel makers now issue class information as to their product, giving the approximate percentage of carbon in each, and as to the class ot uses to which each can be applied. What is given at one time as such classification may be superseded later by improved combinations. I would advise against too strict a specification of composition, as restricting the maker. Rather say what you want as expressed in the physical qualities you may require. Physical tests can be applied by any user of steel. Chemical tests are not to be trusted to, except as conducted by those well skilled in metallurgy. As an indication of how to adapt steel to various uses, let me present the

Average Physical Qualities and Limits of Carbon of Machinery and Structural Steel Manufactured by the Midvale Steel Company.

Class.	Carbon.	Tensile Strength.	Elastic Limit.	Extension.	Contraction.	
O.....	.10 to .19	57,000	26,790	30 %	58 %	Parts like car axles that are subject to shocks.
I......	.20 to .29	68,000	31,960	26 %	50 %	
II	.30 to .39	82,000	38,540	22 %	45 %	Machinery steel for ordinary cases, boring bars, etc.
III. ..	.40 to .49	93,000	43,710	18 %	38 %	Crank from III. to IV.
IV....	.50 to .59	105,000	49,350	14 %	30 %	Wheel tires, large or medium sizes.
V.....	.60 to .69	115,000	54,050	11 %	20 %	
VI ...	.70 to .79	125,000	58,750	9 %	15 %	Spring steel.
VII ..	.80 to .89	135,000	63,450	6 %	10 %	Tool steel.

In steel forgings with a cross-section equivalent to six inches diameter or over, having selected the class you think best suited, word the order thus: "to have the physical qualities of Class ( )." This will enable the steel maker to make allowance for the forging that is to be done with the piece, such work changing the steel to some degree.

The list I have given you can be applied to anv maker if by means of it you indicate just what you do want. Let the information furnished by the drawing room be as explicit as possible, to avoid mistakes and to save time in executing the work.

The designer of machines must in his mind construct, and show by his drawings how to construct to the most minute particular. Without this forethought the question will come up in many cases as to how a machine is to be put together, and, too late, the designer will find that alteration must be made to make erection possible. Let every oil hole be indicated; show what "fits" are to be driven and what ones loose, according to the system of tight and loose fits that may hold in the establishment. All that can be told you and all worth your heeding in engine design would make many lectures of one hour each and not nearly exhaust this vast and important subject. The detail of this theory of machine design should come from the several professors, my plan being rather to point out the importance of what they teach you.

As you are limited, in selection of sizes of all parts, to the shop sizes adopted, so you should limit many of your thicknesses to merchant length of bolts.

It is quite possible in a manufacturing establishment to carry bolts in stock to such length as the special manufacture may call for. In such case all thicknesses that are to be held together by body-bound bolts and nuts, or by black or loose-fitting bolts even, should be made to result in the use of bolts of stock lengths as their length may vary in short bolts, by one-eighth, and longer ones, by one-quarter or one-half inch. The bosses on rough castings may be raised in advance to some practical height that will result in a good-looking job, of bolts neither too long outside of the nuts or too short to come through the nut, with standard length of bolt.

Let me, too, impress on your mind the thoughts that should obtain when you are arranging your mode of fastening. I make it a rule never to use tap bolts when a through bolt is possible; *never to use a tap bolt when its use can be avoided.* Make body bound bolts

serve as dowel pins whenever you can. Never use jam nuts out of place; any nut that is applied to a bolt, holding metal to metal, will not be helped by a second or jam nut. The only place for jam nuts is when the controlling nut cannot be screwed up tight, as on the wedge or key of connecting rods, in this case holding the controlling nut to place by one wrench, a second nut will jam it fast.

Keying or Fitting Wheels to Shafts.—I would advise you to study well the best methods of securing wheels to shafts, the proper proportions of keys; a wheel with its hub fitting the shaft loosely cannot be made secure by taper keys. When I can do so, I use for light or heavy wheels split hubs with tightening bolts. Any armed wheel large enough in diameter may be made with solid rim, but split hub. The hub so split can be sprung open to let it slide to place on the shaft, and upon removal of the wedges used to spring it open, it will close to place on the shaft, when a straight well-fitted key will prevent its slipping in driving, and through bolts will draw the hub tight to place. Bear this method in mind, and use it when you can.

How to Turn a Wheel so that it will Run True.—Always hold a wheel on the mandrel upon which it is turned in the manner it is to be held on the shaft when done. If the wheel is to held by set screws, so hold it while it is in the lathe. A wheel held one way in turning lathe and then used in some other way on the shaft is sure to run out of true.

This must be known in the drawing room, and be followed up in the shop.

As to the Ownership of Designs.—No draughtsman has the right to appropriate the knowledge of the firm employing him to use as an inducement to others in the same line to employ him at higher wages. More than one otherwise good man has lost his place by having been found making notes of designs for his private use. Some houses may be willing to hire men so loaded with stolen information, but they seldom respect or trust them.

Each engineer should, in early professional life, begin a personal note-book, but that note-book should be what he can expose freely to any one who employs him, as containing nothing to which he is not entitled. Every one is the sole owner of the methods and formulæ he originates; to extend his facility of execution is indicative of his skill.

In this note-book should be recorded everything that will save mental work; all formulæ that may enable him to proportion parts

of machinery or aid in estimates. The published engineer's pocket-books, such as those of Molesworth, of Trautwine, of Nystrom, etc., are only the printed notes of what such men have begun by collecting for their own use. Any one of such volumes, rebound and interleaved with ruled writing paper, serves a good purpose. But the card system of memoranda has been the most useful to me. Cards, 3 inches by 5 inches, with a red line at top and blue lines over the rest of the card, can be carried in one's pocket, and serve a good purpose for writing or sketching on, and can then be preserved in a box or drawer in alphabetical order. Some houses use the card system to advantage in all their drawing room records. They use them for catalogue of the library, and of all the cases containing pamphlet literature, for price-lists and all printed matter worth preserving. Envelopes, open at the end, of the same size can hold clippings from papers better than a scrap-book, or until enough have been collected on one subject to make a scrap-book preferable.

It has been my custom always to supply every draughtsman with blank books cheaply bound, on which they are to make all calculations, and to use as freely as paper for sketching. They must be dated on each page or less, and thus all progress of design can be preserved, often to the advantage of the subordinate, and capable of protecting him from unjust suspicion of error. If errors have been made they can be traced on such books. In patent cases such notes frequently play a very important part. I may later refer to instances where the preservation of such notes and sketches have become of historical importance.

The mechanical draughtsman should learn to make free-hand designs neatly and rapidly. His pencil will aid in design and record his thoughts.

School your eyes to appreciation of size and of minute difference in form and size.

It has been to me a lasting regret that I did not become familiar with shorthand in early life when I might have been a rapid phonographer. We too often leave such things too late—when we are too old to learn new automatic motions.

Tracings and Blue Prints.—One class of work in the drawing room requires much care, and this is in relation to the tracings sent out as information connected with estimates for work.

In England a number of the leading establishments employ a staff of women, working in an apartment separate from the drawing

room, who make tracings on cloth or paper. Such tracings must give all needful information to enable the recipient to judge of the merit, and yet must not be in the form of working drawings giving detailed information of what may be termed trade secrets. This class of tracings covers foundation construction required to erect machinery.

The introduction of the several methods of blue printing, say of white lines on a blue ground, or the developing process of blue or black lines on a white ground, made from tracings by direct exposure or contact printing, is revolutionizing this kind of work; but in spite of the facility offered by this system, many houses adhere to tracings as attracting more attention and seemingly showing more attention to the subject. You will do well to give some thought to this subject, and learn to construct expressive drawings that tell enough, and yet give no information not required in each case.

You must learn to guard the technical detail that cannot be protected by patents, and that constitute a large part of the engineer's stock in trade. This may not seem to agree with the desire to extend knowledge. We are, as engineers, working for a living, and must follow the laws and customs of trades. If we are to profit by our talent we must protect our original thought, when not by patents, by moderate caution.

The best form of teeth for gearing, spur, bevel, as well as worm wheels, must be thoroughly understood by the skilled draughtsman. First, as to the use to which they are to be applied, and then as to the form of the teeth best suited to this use.

Most machine shops publish their list of gearing, and such published list is sent to those likely to want castings from their patterns. A well expressed gear wheel list should tell concisely the pitch, face, character of wheel as relates to arms, rim and hub, but above all else, the form of the tooth, whether epicycloid or involute; if the former, the diameter or radius of the sweep used in forming the teeth. Willis, Comus, and other writers on teeth of wheels, should be studied and mastered. For several years of my life in the drawing room, I laid out and filed to shape all the templates used in the establishment. I took this work on myself for the purpose of perfecting myself in the same work, and leading up to the invention of a machine that could do this work, not in forming a template, but in making the cutters to be used in the gear cutting machines.

Very few establishments will bear the expense of such machinery, and without the cutter forming machine, the system of templates must be continued. You have been taught, to a limited extent, the use of the odontograph of Willis and others who have written on this important subject.

Spur gearing of any given pitch to be interchanged, that is to say, to gear one with another through a long series, are struck with a sweep, the diameter of which is the radius of the pinion of the least number of teeth in that series. Following the advice of Willis a pinion of 12 teeth is commonly accepted as the beginning of the series.

If any of you will take the trouble to make a pair of templates, using Willis' odontograph to find the centres from which to strike the crown and the flank of the teeth, or the curves outside and inside of the pitch line; and you also make a similar pair of templates, using a pair of sweeps, the curves of which correspond with the pitch line of each wheel, and with such curves you roll on the convex curve for the crown, and on the concave curve for the flank, a sweep that is in diameter the length of the radius of a pinion of 12 teeth of the given pitch, carrying a scratching joint on its edge, you will find them to agree very nearly, provided you have made no mistake in taking off the striking radii, or in laying out the outer and inner sweep circles.

It is the very great danger of making mistakes with the use of such instruments, that makes most gear makers insist on the more expensive, but much more certain method that has been taught you in your course of study at my request, and from a certain knowledge that you will, sooner or later, be called on to use what you have been taught.

A good working gear list should give, under the heading: spur or bevel wheel—cast teeth in one list; cut teeth in another; in both, number of teeth, pitch or per inch diameter at pitch line, outside diameter and inside diameter, or diameter of the rim of the wheel upon which the teeth are located. The diameter of the sweep used in creating the wheel. The thickness of tooth at pitch line, that the clearance may be known. To these items of information should be added the use to which the first wheel was applied, that it may be found among the drawings. A column for weight of casting will add much to the value of the record.

Let this be my opportunity to say that all records of the drawing room should be in such form as to save trouble and save time. A

very considerable part of the routine work of the draughtsman is expended in estimates. Cost of new machines must be estimated. All large castings, or such as are beyond the guessing power of the foreman of the foundry, will require an estimate of weight, to enable him to prepare for pouring sufficient metal, not only to avoid pouring short, but to avoid having more metal of the kind required than necessary for the casting and to reduce the waste incident to running into pig.

The foundry man ordering the charge of the cupola, makes up the record of his heat and charges the several sorts of metal in the order they are to be run out. It is to the drawing room he comes for the primary information as to weight. The pattern, with much cored work about it, is of no value of itself, being weighed in estimating weights of castings. From this one example you can see how much time will be saved and accuracy assured if the result of every estimate is preserved and checked by actual weights, taken from the foundry books.

The pattern list, drawn up usually by the one who has made the construction drawing of a machine, should go into the pattern shop after it has been copied into the foundry books in the office. It is then, from the foundry accounts in the office, that weights can be obtained, and much trouble can be avoided if the numbers indicating the patterns are noted on the drawing. Among the lists accessible to all in the drawing room is that of the proportion of gear wheels, worked out on the adopted system of the shop.

Fly-wheels, balance wheels, hand wheels with round rims, etc., should not only be preserved in list for ready reference, but should have a record of weight and their value at any given speed when used as a fly-wheel.

In a well regulated machine shop the drawing room should be near to the pattern shop, that information required by the pattern maker may be had quickly, and that the pattern work may be overseen by the responsible head of the designing room.

Hours of Work in the Drawing Room.—For very many years of my shop experience, the hours of work for the draughtsmen coincided with the hours of the machine shop. This, however, is not good practice. Ten hours a day is too long for continued work over the drawing board. Shops running on the ten hour time in the drawing room are now satisfied with less time, say eight. If the work in the machine shop begins at 7 A. M. and ends at 6 P. M.

while the draughtsmen begin at 8 A. M. and stop at 5 P. M., there are two hours lost to the machine shop foreman, or other responsible men, in which they can get information from the drawing room. This is a serious matter. From the first to the last hour of the machine shop day some important work may be delayed if there is no one on hand to answer questions. This difficulty can be got over in two ways: one being to let the chief or the best draughtsmen come early or stay late in orderly and well regulated sequence, but they are seldom able to answer one for the other.

My advice is to have in every fully equipped drawing room one well paid employee, called an *inspector*, whose business is to go over every drawing, seeking for errors, verifying measurements, and calling attention to mistakes, other than mistakes in principle. Let his pay be high enough and his routine work of such nature that he can work ten hours, and he may be checked by a system of fines for mistakes that escape his supervision. I have known this to work well. The work he can do is to make rough card drawings of separate parts of each machine, writing pattern lists, and thus making himself familiar with every part of every drawing, and so able to reply to questions about each machine, as all drawings that he examines must bear his name as examiner with date of signature. A few fines will make him careful, and his supervision of the drawings is sure to save mistakes.

Record of Formulæ and Proportions of Machines.—Where machines are to be constructed in varying sizes, as in the case with machine tools, steam engines, steam pumps, etc., it is customary to build one machine, and when it is satisfactory, a second one is designed, larger or smaller as the case may be, and all intermediate sizes are scaled from the two.

I have always advocated the preservation of the proportionate formulæ in a volume kept for that purpose. Tracings having been made from the drawings of one machine, the dimensions of all parts are not expressed in inches on that tracing, but by numbers from 1 up. This numbered tracing is blue printed for use in the drawing room, but in the book of proportions, opposite each number, is written a formula that will enable a clerk to apply the formulæ to each size of machine to be drawn. The usual rule for originating these formulæ is as follows:

Take difference between nominal size of largest and smallest machine, and difference between corresponding dimensions of parts

required. Divide the latter by the former: the result is a factor which multiplied by Δ (nominal capacity) and increased or diminished by a constant increment, will give the size of part required. To find this increment, multiply Δ of some known size by the factor obtained, and subtracting the result from the size of the part required as above.

Example: Δ of largest $= 72$, Δ of smallest $= 42$.

Largest size of part, 3 inches; similar part on smallest machine, $1\frac{7}{8}$ or 1.875.

$$72 - 42 = 30; \qquad 3 - 1\tfrac{7}{8} = 1.125$$

$$\frac{1.125}{30} = .0375; \qquad .0375 \times 42 = 1.5750$$

$$1.875 - 1.575 = .3 = a.$$

Formula $\Delta\ .0375 + .3 = x$.

To prove this on one of the given sizes:

$$42 \times .0375 + .3 = 1.875 = 1\tfrac{7}{8} \text{ inches.}$$

The same work can be done by scaling, but requires a higher priced man to work out each dimension.

The formula $A\ \Delta + C = x$, is an expression of the same thing worked out thus:

$$a\ 72 + c = 3$$

$$\underline{a\ 42 + c = 1\tfrac{7}{8}}$$

$$a\ 30 \quad = \quad 1\tfrac{1}{8}$$

$$a = 1\tfrac{1}{8} \div 30 = \frac{9}{240}$$

$$\frac{9 \times 72}{240} + c = 3$$

$$c = 3 - \frac{648}{240} = \frac{72}{240}$$

$$\frac{9\ \Delta + 72}{240} = x. \quad \text{To test this } \frac{9 \times 42}{240} + 72 = 1.875.$$

This book of proportions should be the receptacle for all information relating to the manufacturing of machines that are worth preserving.

In doing the work of applying the recorded formulæ to any given case, I cannot too strongly recommend the use of the slide

rule or any calculating machine that can be applied to such work. We are not much used to the slide rule in this country. In England I have seen in one shipyard no less than 30 men, each using the circular or spiral slide rule to work out the calculation required in shipbuilding. So impressed have I been with the value of this instrument, that I have taken the trouble to master its use since I have occupied the chair in the Stevens Institute. A very able engineer in England, lecturing on the slide rule to mechanics, said all educated men should learn the rules of arithmetic, but. when once master of them, they should be given up in all cases when mechanical calculators can take their place. The saving in time is very great. The cylindrical slide rule, with a spiral line of figures, gives, in a small, handy compass, a slide rule which, if straightened out, would be over 82 feet long, and would take a room 164 feet long to operate it in. This slide rule reads up to five figures, and with it all ordinary calculations can be quickly accomplished. A smaller instrument, the size of a watch, has a scale only 4 or 5 inches long, but with it much can be done.

In concluding to-day's lecture, let me say that I do not, in my own practice, allow any latitude in the drawing system in use. If drawings are to be made, as usual in machine shops, on the third angle of descriptive geometry, let the rule be without exception. Place each view or elevation nearest to the part on the front elevation that is to be represented. Plan over the front elevation, never below it.

Bear in mind what you express, with your full knowledge of what you intend, is to be read by workmen who cannot be expected to exercise judgment, and must follow the drawings interpreted on one fixed system.

You are making an illustration that is to be put into actual form by men of limited knowledge of drawing. I am sure your careful consideration of this important subject can lead to no other conclusion; and yet I have seen many costly mistakes come from the non-observance of the designer of this important rule. The simpler the form drawn, the more likelihood is there of error from the non-observance of the adopted system.

ANIMAL, MARINE AND VEGETABLE OILS USED IN LUBRICATION—THEIR CHEMICAL REACTIONS AND THE METHODS OF DETECTION IN MIXTURES.

BY PROF. THOS. B. STILLMAN.

DURING the past few years marked advances have been made in the qualitative and quantitative chemical reactions of many of the animal and vegetable oils, so that identification in mixtures has become more positive; yet the production of new oils by the distillation of waste fats and greases has opened up an enterprise to the manufacturer and a field of further inquiry to the chemist.

Many of these products form good lubricants, either alone or mixed with varying proportions of mineral oil, and they give that "body" requisite, when moderate temperatures in lubrication are produced, that mineral oils often fail to possess.

The consumption of fish oils, especially refined menhaden oil, for similar purposes, has also largely increased, and in the cheaper grade of lubricants so much sophistication is practiced that in many instances four different oils have been found in one sample.

This adulteration is even more serious from a commercial standpoint, when oils of the finest quality and grades are so admixed that samples of absolutely pure sperm, whale, lard, and olive oils are very difficult to obtain. The admixture of lard and cotton-seed oil in olive oil, of menhaden oil in whale oil, of whale oil in sperm oil, of tallow oil in lard oil and neatsfoot oil, all of which is now carried on as adulterations, complicates the subject of the chemical analysis of lubricating oils. When the above are used in the lubricant, and where it is desirable that two or, at most, three tests should be sufficient to identify an oil, it will be found that oftentimes six or seven different reactions are requisite.

In deciding upon what chemical tests constitute the criterion with all, or at least the majority of the oils used, so that a critical

comparison can be made of their individual tests, and then a resumé for tests in occurring mixtures, I have included the following:

1st. Specific Gravity. 2d. Maumenè's Test. 3d. Massie's Test, and Heidenreich's reaction with $H_2 SO_4$. 4th. Saponification Equivalent. 5th. Congealing or solidifying point. 6th. Iodine Absorption. 7th. Viscosity.

Experience has shown that the above tests will, in most cases, indicate any single oil absolutely, and in mixtures generally used for lubricating purposes, the animal, marine and vegetable, mixed with the mineral. In special cases, where two seed oils or two animal oils of similar chemical reactions are used with a mineral oil, the total adulteration will be indicated, and then identification of the like oils left for special tests.

Specific Gravity.

This important test is a confirmative one when a single oil is under examination, and an indicator in certain admixtures with mineral oils. Any abnormal figure obtained, either too high or too low, from the standard required is indicative of the use of certain oils.

For instance, a lubricating oil of specific gravity .897, gave, upon saponification and separation, 30 per cent. of animal oil, and 70 per cent. of mineral oil of specific gravity .889. If a comparison be made of the specific gravity of the original oil, and the mineral oil separated therefrom, and the percentage of the latter taken into account, it will be found that the specific gravity of the remaining oil should be .916, which would indicate lard oil or neats-foot oil as the animal oil added, and the requisite confirmative tests can then be made.

It is true in many cases, where the adulteration has been made with two or even three oils of about the same specific gravity, that this test gives no *direct* indication of the oils composing the mixture (for instance, lard oil, specific gravity .916, olive oil, specific grav-

ity, .917, and tallow oil, specific gravity, .915), yet the fact that the specific gravity is .916, and the oil entirely saponifiable, shows that a very considerable number of oils cannot be present in any quantity, such as rosin oil, cotton-seed oil or menhaden oil, thus *indirectly* proving of value as an indicator.

Of the various methods and appliances used for the purpose of determining the specific gravity of lubricating oils, the author gives preference to the Westphal balance, as being expeditious and sufficiently accurate.

Where it is desirable to determine the gravities at higher temperatures than 20° Cent., the modification of the balance, as suggested by Bell (*Chem. Centralblatt*, 1879, 127), is used.

An accurate Baumè hydrometer will fulfill the conditions required at normal temperature, and where it has been carefully tested is more expeditious than the Westphal balance.

If small amounts of the oil only are obtainable, a small Picnometer, or the Araeo-picnometer of Eichhorn can be used. This invention (Deutches Reichs Patent, No. 49,683) is described by Dr. H. Hensoldt, of the Petrographical Laboratory of Columbia College, New York, in the "Scientific American Supplement" of March 21, 1891, with a drawing. The new and important feature of this instrument consists in a small glass bulb (attached to the spindle), which is filled with the liquid whose gravity is to be taken. Thus, instead of floating the entire apparatus in the test fluid, only a very small quantity of the latter is required.

The glass bulb, when filled with the test fluid, is closed by means of an accurately fitting glass stopper, and the instrument is then placed in a glass cylinder filled with distilled water at 17.5° Cent.

The gravity is then at once shown on the divided scale in upper portions of the spindle.

This apparatus is quite simple, very accurate, and will undoubtedly be of great use.

The following table converts degrees of the various hydrometers into specific gravity. [Liquids lighter than water.]

Baumé hydrometer, at 15° Cent., $\dfrac{144.78}{144.78 + n}$ = specific gravity.

Brix hydrometer, Fischer " at 15.6° Cent., $\dfrac{400}{400 + n}$ = specific gravity.

Gay-Lussac, 4° Cent., $\dfrac{100}{100 + n}$ = specific gravity.

Beck, 12.5° Cent., $\dfrac{170}{170 + n}$ = specific gravity.

Cartier, 12.5° Cent., $\dfrac{136.8}{126.1 + n}$ = specific gravity.

n = degrees indicated upon the spindle.

For complete details regarding the apparatus used and methods employed in determining the specific gravity of fixed oils, consult:

"Untersuchungen der Fette, Oele and Wachsarten," by Dr. Carl Schaedler, pp. 38–40.

"Analyse der Fette and Wachsarten," by R. Benedikt, pp. 50–56.

"Commercial Organic Analysis," by A. H. Allen, pp. 13–18.

"Oils and Varnishes," by James Cameron, pp. 208–211.

"Spon's Encyclopedia of the Arts and Sciences," edited by C. G. W. Lock, p. 1465.

The following references include special methods relating to specific gravities and results obtained upon oils:

"The Adulteration of Fatty Oils," G. Richter, including specific gravities and the use of Laurot's Oleometer. Seifenseid Zeitschrift, Vol. 16, p. 187, Vol. 17, p. 199; also Journal Society Chem. Industry, Vol. II., p. 384.

"Investigations on Lubricating Oils," S. Lamansky. Ding. Poly. Journal, 248, p. 29, etc.

"The Methods of Examining and Chemistry of Fixed Oils," A. H. Allen. Journal Society Chem. Industry, Vol. V., p. 65.

"On the Densities and Refractive Indices of Certain Oils," J. H. Long. Amer. Chem. Journal, Vol. X., p. 392; also Journal Society Chem. Industry, Vol. VII.

"Specific Gravity of Some Fats and Oils," C. A. Crampton. Amer. Chem. Journal, Vol. XI., p. 232.

"Die Fette Oele," Dr. George Bornemann, pp. 231, 232.

"The Examination of Lubricating Oils," Thos. B. Stillman. THE STEVENS INDICATOR, Vol. VII., 1890, p. 211.

Maumenè's Test.

The rise of temperature produced when sulphuric acid is brought in contact with certain oils was first investigated by Maumenè, and the results of his experiments published in Compt. Rend., Vol. XXXV., p. 572.

The subject has been investigated by Fehling, Faist, L. Archbutt, C. J. Ellis, A. H. Allen and others, with the result that this test has been generally accepted as of importance in the distinction of many oils in mixtures.

Where a mixture of oils has been analyzed and the components recognized the proportions oftentimes can be determined by this reaction: that is to say, suppose the oil under examination to show a rise of temperature of 80° Cent., and the oils found by analysis to be lard oil and menhaden oil; their relative proportions can be determined by the following formulæ :

$$W_1 = W_3 \frac{t_3 - t_2}{t_1 - t_2}$$

$$W_2 = W_3 \frac{t_3 - t_1}{t_2 - t_1}$$

W_1 = Proportion by weight of menhaden oil.
W_2 = " " " " lard "
W_3 = Weight of mixture.
t_1 = Temperature of menhaden oil.
t_2 = " lard "
t_3 = " mixture.

Lard oil alone when treated with sulphuric acid gives a rise of temperature of 40° Cent., menhaden oil, under similar conditions, a rise of 128° Cent. Using these values in the above formulæ we obtain 54.6 per cent. lard oil and 45.4 per cent. menhaden oil.

In a mixture containing a mineral oil mixed with an animal, marine or vegetable oil the distinction would be even more pronounced, since the mineral oil shows but a very slight increase of temperature (generally from 2° Cent. to 5° Cent.). The increment of temperature would be dependent upon the other oil added to the mineral oil.

Briefly stated, the rise of temperature of the following oils would be :

	Name of Observer.				
	Maumené.	Schaedler.	Archbutt.	Allen.	Stillman.
Lard oil	40°	.	..	41°	39.5°
Tallow oil	41°–43°	..	..	..	39°
Neats-foot oil	45°	50°	43°	..	40°
Oleo oil	..	..	37½°	38½°	37°
Elain oil	..	..	..	..	38°
Sperm oil	..	..	51°	45°–47°	48°
Whale oil	..	..	92°	91°	92°
Menhaden oil	..	..	123°–128°	126°	128°
Dog-fish oil	..	..	..	..	80°
Cod liver oil	102°–103°	103°	..	113°	110°
Crude cotton-seed oil	..	69.5°	70°	67°–69°	74°
Rape oil	58° F.	..	..	..	60°
Castor oil	47°	48°	46°	65°	45°
Olive oil	42°	43°	41°–45°	41°–43°	42°
Rosin oil	..	28°	..	18°–22°	10°
Mineral Lubricating oil	..	..	..	3°–4°	3°
Earth-nut	67°	67°	47°–60°	..	..
Rosin oil, 1st run	..	..	..	..	33°
" " 2d "	..	..	..	..	10°
" " 3d "	..	..	..	..	10°
Sea Elephant	..	..	..	..	65°

It will be noticed that Schaedler gives a rise of temperature of 28° for rosin oil; Allen, a rise of 18° to 22° for the same oil, and that my determination was 10°.

A difference so great led me to obtain the various grades of rosin oil, "1st, 2d and 3d runs," when the above discrepancy was easily explained.

Rosin oils of the "1st run" is a white, opaque, thick liquid, containing all of the water of the rosin from which it was distilled, and it is this water that causes the rise of temperature above 10° when the oil is mixed with the sulphuric acid.

Rosin oils of the "2d and 3d runs" are clear, limpid, dark-red colored fluids, practically free from water, and when treated with $H_2 SO_4$ do not indicate more than 10° rise of temperature.

From these tests I conclude that both Schaedler and Allen tested rosin oil that was a mixture of the "1st and 2d runs," or of an oil not properly separated into the different distillates.

The method of applying this test will be found in "Untersuchungen der Fette, Oele and Wachsarten," Dr. Carl Schaedler, pp. 120-123.

"Analyse der Fette und Wachsarten," Dr. R. Benedikt, pp. 190-191.

"Spon's Encyclopedia," p. 1471, gives a modification of the process in which sulphuric acid of 1.845 spec. grav. is used. Consult also,

"Chemical News," Vol. XLIII., p. 195.

Archbutt, "Journal Society Chem. Industry," Vol. V., p. 303.

C. J. Ellis, "Journal Society Chem. Industry," Vol. V., p. 150.

A. H. Allen, "The Analyst," Vol. II., p. 102.

Maumenè, "The Chemical News," Vol. 40, p. 46.

Stillman, "Journal Analytical Chemistry," Vol. III., p. 366.

Casselmann, "Zeitschrift für Analytical Chem.," Vol. VI., p. 484.

Maumenè, "Compt. Rend., 92, p. 721.

Dr. G. Bornemann, "Die Fetten Oele," p. 228.

Color Reactions of Oils with Nitric and Sulphuric Acids.

Of the many color tests introduced for the identification of simple oils, preference is given to Heidenreich's sulphuric acid test and Massie's nitric acid test.

The color reactions of Chateau* in which barium poly-sulphide, zinc chloride, stannic chloride, phosphoric acid and mercuric nitrate, in solutions, are used, while very interesting, seldom are of any advantage over the two tests noted above. Glassner's† nitric acid reactions are practically the same in results as Massie's, so that no advantage would be obtained in including the former.

Heidenreich's test is as follows:

A clear glass plate is placed over a piece of white paper, ten drops of the oil under examination are placed thereon, and one drop of concentrated sulphuric is added.

The color produced when the acid comes in contact with the oil is noticed as well as the color produced when the two are stirred with a glass rod. Many oils give off characteristic odors during the reaction, especially neats-foot oil, whale oil and menhaden oil.

Massie's Test is thus performed:

Nitric acid of specific gravity 1.40, free from nitrous acid, is mixed in a test tube with one-third its volume of the oil, and the whole agitated for two minutes.

The color of the oil after separation from the acid is the indication.

In mixtures of oils, the characteristic colors produced, by either Heidenreich's or Massie's tests, are often clouded, and in many instances no inferences can be drawn, yet with single oils the reactions are often distinctive and sufficiently strong to give confirmatory results.

In cod-liver oil, or whale oil, when mixed with a mineral or even vegetable oil, the characteristic brilliant violet color produced with sulphuric acid cannot be mistaken. This color, due to the presence of cholic acid, is found in most of the fish oils, but is much more pronounced in cod-liver oil.

The following table will indicate the colors produced by Heidenreich's and Massie's tests.

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*Spon's Encyclopedia, Vol. IV., pp. 1472-1475.

†Chem. Centr., 1873, p. 57.

	HEIDENREICH'S TEST.		MASSIE'S TEST.
	Before stirring.	After stirring.	
Lard oil	Yellow	Brown	Yellow.
Tallow oil.	Yellow	Orange	Colorless.
Neats-foot oil	Yellowish	Red brown	Red.
Oleo oil	Colorless	Orange	Pink.
Elain oil	Light green (turning to brown)	Brown	Orange Red..
Sperm oil	Brown with purple streaks	Reddish brown.	Red.
Whale oil	Red violet	Violet brown	Red.
Menhaden oil	Red	Brown	Dark Red.
Dog-fish oil	Violet	Dark brown	Orange.
Cod-liver oil	Red violet	" "	Orange red.
Crude cotton-seed	Brilliant red	Brown	Brown.
Refined " "	Reddish brown.	Red	Orange Red.
Rape oil	Yellow brown	Brown	Orange.
Castor oil	Light yellow to brown	Pale Brown	Orange.
Olive oil	Light green	Greenish to light brown	Yellow to Greenish.
Rosin oil	Brown	Brown	Orange.
Earth-nut oil	Yellow to orange	Greenish	Reddish.

Full details regarding these tests will be found in :

"Oils and Varnishes," Cameron, p. 234.

"Dictionary of Chemistry," Watts, Vol. III., p. 1428.

and in connection with the use of sulphuric or nitric acid in the qualitative examination of oils by other chemists, the following references are given:

A. Andoyand, "Compt. Rend.," Vol. 101, p. 752.

Flükiger, "Zeitschrift für Analyt. Chem.," X., p. 235.

Allen, "Moniteur Scientif." XIV., p. 724.

H. Levy, "Chem. Zeit. Rep.," XII., p. 238.

A. Kremel, "Chem. Zeit. Rep.," XIII., p 46.

Stillman, "Jour. Analytical Chem.," III., p. 368.

Pontet, "Chem. Zeitung," also "Chem. News," Vol. XXXIX., p. 136.

Wideman, "Moniteur Scientif. Ques.," May, 1881.

M. Zecchini, "Les Mondes," May 13, 1882.

H. Meyer, "Zeit. für Analy. Chemie," Vol. 23, Part III.

J. L. Rossler, "Zeit. für Analy. Chem.," Vol. 24, Part III.

R. Brulle, "The Chemical News," Vol. 57, p. 211.

Saponification Equivalent.

The "saponification equivalent" of any oil is the number of grammes of the oil decomposed by one litre of a normal solution of an alkali.

The method, as given by Koettstorfer will be found in "Zeit. fur Anal. Chem.," Vol. 18, page 199.

More complete details of the process will be found, however, in Schaedler, "Untersuchungen der Fette," Oele, etc., pages 130–136.

The procedure is as follows:*

Two grammes of oil are weighed in a tall beaker ($75^{c.c.}$ capacity), $25^{c.c.}$ standard alcoholic potash are added, and the whole heated on a water-bath. When saponification is complete, the solution is taken from the water-bath, $1^{c.c.}$ of alcoholic phenolphthalein is added, and it is titrated back with half-normal hydrochloric acid.

From the difference between the amounts of hydrochloric acid required by $25^{c.c.}$ standard alkali, and the amount used in the above titration, the amount of K HO, combined with the acids of fat is calculated. The standard potash solution is to be titrated afresh on each occasion, and before testing with the standard acid, $25^{c.c.}$ of it should be heated for fifteen minutes on a water-bath, as in the saponification of the sample.

	Saponification Equivalent.	Percentage of K HO for Saponification.
Lard oil	285—296	19.1 to 19.6
Tallow oil	285—296	19.1 to 19.6
Neats-foot oil	285—300	19.2 to 20.3
Sperm oil	380—454	12.34 to 14.74
Whale oil	250—303	18.85 to 22.44
Menhaden oil	250—303	19.2
Cod-liver oil	250—303	18.5 to 21.3
Crude cotton-seed oil	285—296	19.10 to 19.66
Rape oil	313—330	17.02 to 17.64
Castor oil	309—319	17.60 to 18.15
Olive oil	285—296	19.1 to 19.6
Rosin oil	290—330	17. to 19.3
Earth-nut oil	285—296	19.13 to 19.66

* Oils and Varnishes, Cameron, p. 247.

The Cold Test.

The degree at which an oil becomes semi-solid and refuses to flow freely is considered the "Cold Test," and is performed as follows:

50c.c. of the oil is transferred to a narrow bottle (capacity 100c.c.), stoppered with a rubber stopper, through which is inserted a thermometer, the bulb of which reaches an inch or more into the oil.

The bottle is placed in a mixture of ice and salt, or other freezing compound, and retained there until the oil becomes solid. It is then removed and allowed to warm until the contents become somewhat thinner in consistence. The bottle is inclined from side to side until the oil begins to flow, when the temperature is taken.

At this particular temperature the oil is neither at its normal fluidity, nor is it solid, and while this method does not correctly indicate the exact temperature of the solidifying point, it does show the point at which the oil ceases to flow readily; the important one to the oil inspector.

In lubricating oils, to be used in railroad practice, this "cold test" is a vital one, and receives in the laboratories of the different railroads of the United States considerable attention.

A mineral lubricating oil, "non-paraffine," of good quality does not show any material difference in its consistency at 25° Cent. or 10° Cent., but a radical change would be indicated at 10° Cent. if some of the animal or vegetable oils were a component.

While it is true that no proportion of one or the other can be indicated by the "cold test," and that this test might not properly be classed as a chemical but rather as a physical one, yet so important is this property of congealing in lubrication, and as all laboratories connected with railroad work rely strongly upon it, I have included it as one of the principal ones.

In connection therewith is here included the drawings of the apparatus used for this purpose in the chemical laboratory of the Chicago, Burlington and Quincy R. R. Co., Aurora, Ill. (Geo. H. Ellis, Chief Chemist).

Figure 1 represents the glass apparatus with the thermometer arranged for the "cold test."

Figure 2 represents the "cold box" to contain the freezing mixture and in which the oil is tested.

The following determinations of the "cold test" made in my laboratory will show the wide range between many of the oils in this regard used in lubrication:

Elain oil	6° C.
Saponified red oil	5°
Prime neats-foot oil	4°
White neats-foot oil	— 4°
Pure "hoof" oil	— 6°
Prime lard oil	7°
"No. I." lard oil	7°
"XXX" " "	3°
American sod oil	1°
English "	24°
Tallow oil	26°
Dog-fish oil	— 7°
"Right" whale (Pacific)	0°
Unbleached "bowhead" whale (Pacific)	— 7°
"Bleached" whale oil (Pacific)	— 13°
"Natural" sperm oil (Pacific)	0°
Bleached " "	— 4°
Herring oil "	0°
"Natural winter" sperm oil (Atlantic)	— 1°
"Bleached winter" sperm oil (Atlantic)	— 4°
"Natural spring" sperm oil (Atlantic)	10°
"Bleached spring" sperm oil (Atlantic)	8°
"Natural winter" whale oil (Atlantic)	— 2°
"Bleached winter whale oil (Atlantic)	— 5°
"Natural spring" whale oil (Atlantic)	5°
"Bleached spring" whale oil (Atlantic)	2°
"Prime crude" menhaden oil	— 4°
"Brown strained" menhaden oil	— 7°
"Light strained" menhaden oil	C. — 7°
"Natural winter" menhaden oil	— 9°
"Bleached winter" menhaden oil	— 12°
"Extra bleached winter white" menhaden oil	— 11°
"Bank" oil	— 4°
"Straits" oil	— 7°
Sea elephant oil	5°
"Black fish" oil	— 8°
Rosin oil, "1st run"	3°
" "2d run"	— 19°
" "3d run"	— 20°
Castor oil	— 18°
"Crude" cotton-seed oil	— 7°
"Prime summer yellow" cotton-seed oil	5°
"Off quality" summer yellow cotton-seed oil	— 6°
"Prime quality" winter cotton-seed oil	— 10°
"Off quality" winter cotton-seed oil	— 8°
"Prime quality" summer white cotton-seed oil	3°
"Off quality" summer white cotton-seed oil	— 8°
"Prime quality" winter white cotton-seed oil	— 9°
"Off quality" winter white cotton-seed oil	— 5°
"No. 1" French "Degras" oil	25°
"No. 2" " " "	25°
English "Degras" oil	18°
Olive oil	3°
"Oleo" oil	25°

In the specifications, for the supply of oils to the various railroads, it is generally stated what degree is required for the "cold test." Thus the P. R. R. requires as follows :

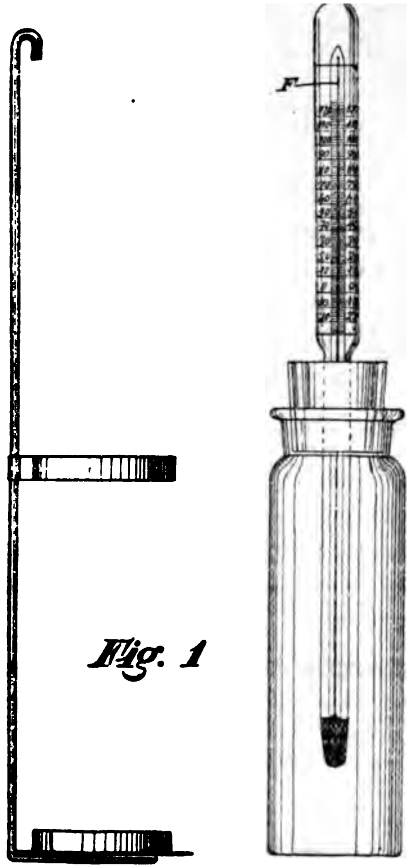

F

Fig. 1

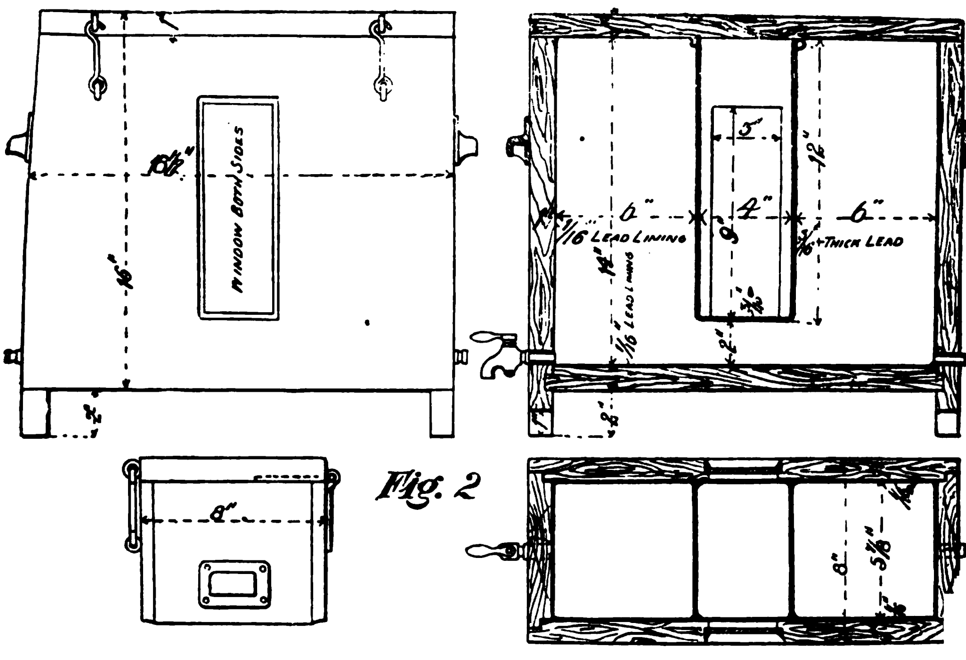

WINDOW BOTH SIDES
16½"
16"
8"
6"
4"
5"
12"
1/16 LEAD LINING
1/16 THICK LEAD
5⅞"

Fig. 2

Lard oil, 8° Cent.,	November 1 to	April 1.
Tallow oil, 8° Cent.,	"	"
Neats-foot oil, 8° Cent.,	"	"

B. & O. R. R. Co.:

Engine oil.	—From October 1	to May 1,	below	9°	Cent.
Passenger car oil.—	"	"	"	"	"
Freight car oil. —	"	"	"	"	"

C., B. & Q. R. R. Co.—Black Engine oils:

"Summer oil"	must	flow at	15°	Cent.	and above.
"25°" oil	"	"	— 1°	"	"
"15°" oil	"	"	— 9°	"	"
"Zero" oil	"	"	— 15°	"	"

(TO BE CONTINUED.)

THE PIKES PEAK RACK RAILROAD.

BY GUS. C. HENNING, M. E., '76.

IN constructing a railroad to the top of Pikes Peak, in Colorado, a very difficult problem presented itself, on account of curves, grades and elevations, as well as the nature of the ground to be traversed.

No line practicable for ordinary adhesion engines could have been laid down without adopting the spiral tunnel system, or, at least, making such a circuitous and costly road that it would have been a losing enterprise.

The elevation of the starting point of the railroad at Manitou Springs, Col., is about 6,600 feet above sea level; the top of the Peak about 14,200 feet; grades varying from 3 to 25 per cent.; curves as high as 16 degrees.

The system adopted avoided frequent crossing of mountain torrents and made the use of only a few short plate girders necessary.

The conditions of traffic were that the single engine should take up hill two cars weighing, when loaded by 100 passengers,

42,000 pounds, sufficient fuel for the round trip and water for one half the trip; speed to be on the heaviest grades about four miles per hour, with a maximum speed on the nearly level portions of the road of 12 miles per hour.

At these rates the round trip, if necessary, could be made in less than three hours, giving visitors ample time on the summit. On a road of such character the safety devices would, of course, have to be of exceptional construction, and certainty of action, for any failure on their part would mean almost certain destruction of all persons on the train at the time. That absolute safety has been assured will be seen from the description given below.

The system adopted is that devised by the Swiss engineer, Roman Abt, who has built many similar roads in Switzerland, Turkey, India and South America. The particular design of this road in regard to location, details and construction is the work of Mr. W. Hildenbrand, the eminent engineer, who controls the Abt patents in this country. The inspection and fabrication of the material for rack bars, chairs and connections as well as switches, which is a great part of the mechanical engineers' province in this work, was in charge of the writer. The engines, however, were built by the Baldwin Locomotive Works, of Philadelphia. The road happens to be the first one of its kind in this country, at the same time being the longest, and having the heaviest grades and greatest difficulties to be overcome.

Its exact length is 46,158 feet, or nearly 8¾ miles. The altitude of its initial point is 6,600 feet, rising 7,600 feet to the summit at 14,200 feet above sea level. Maximum grade is 25 per cent.; over 22 per cent. of the line having a grade of over 22½ per hundred.

The grades of the entire line are:

22½—25%	1,188—1,320	feet per mile.	 10,229	feet long.
19½—22½%	1,038—1,188	" "	 6,820	"
15½—19½%	818—1,030	" "	 7,675	"
12½—15½%	660— 818	" "	 4,295	"
12½% or less	660 or less	" "	 17,139	"

There is no level track anywhere except a few hundred feet on the summit.

There are about 28,376 feet of tangent, the remainder being curves up to 16 per cent.

The T-rails are 40 lbs. per yard, Illinois Steel Company pattern, same as used on the Rock Island Route, and are laid on sawed red spruce and oak ties, 8-inch face 7 inches deep and about 9 feet long, spaced 20 inches centre to centre, all laid in stone ballast, much of which had to be carried up hill for a considerable distance as that found in higher altitudes was not serviceable. Although laid in this ballast, the downward forces are so great that the ties were also anchored from time to time according to the grade, varying from 200 to 1,000 feet intervals. These anchors are made in two ways; the first is by rods held by anchor bolts leaded in bed rock, and the second is by struts abutting against the ties at upper end and rock at the lower end, whichever was most convenient.

The pair of rack rails are placed side by side midway between T-rails, and are rolled steel bars, with teeth cut out of the solid bar so as to be alternate in opposite bars, giving full bearing of pinion teeth on one tooth at least, at all times, securing continuous contact.

These rack bars are all 4⅝ inches deep, standing on edge, and varying in thickness from ⅞ to 1¼ inches according to grade, and are bolted to the die-forged steel chairs, which themselves are secured to the ties by lips and lag screws. To be able to provide for expansion and contraction due to caloric changes, these bars are made about 84 inches long, being held at the centre by neat bolts through bars and chairs, and at ends by bolts through clearance holes in bars and neat holes in chairs, so that the expansion of all bars takes place from the centre of the bars toward the ends in all cases, the bars being fixed to the centre chair.

The steel for bars was made at the Cambria Iron Works (Bessemer Department), while that for the chairs was made and rolled by the Spang Steel and Iron Company, of Sharpsburg, Pa.

The rack bars were rolled by the Johnson Company, of Johnstown, Pa., who also did all the work of fabrication of racks, chairs, bolts and switches, under the direct supervision of the writer.

It was originally the intention to follow the foreign practice of making the chairs of cast metal, either iron or steel, but at the suggestion of the writer they were made by die-forging out of rolled plates to his design and proposed method.

The main reasons for making this change were of commercial as well as technical character. These chairs could be made much quicker and cheaper by die-forging, and would certainly be much better as regards material, and more accurate in workmanship. By this method there was every prospect of making a uniform product as regards quality and shape, and the inspection would be reduced to a minimum.

The material from which the bars were to be made was to be Bessemer or Open-hearth steel, as preferred by the maker, and the specifications to be fulfilled, were prescribed as below, when testing standard pieces cut from the bars after being rolled.

Tenacity of material as determined from test pieces about ½ square inch area was to be 70-76,000, giving an elongation of 25 per cent. in 8 inches, and a reduction of area of 45 per cent.

The steel for the chairs. was to give the following results: Tenacity, 60-66,000 pounds; elongation in 8 inches, 18 per cent., and reduction of area of 40 per cent.

The material for rack bars and chairs was carefully and frequently tested, and was found to be of unusual uniformity in every respect. The material for rack bars was of unusual quality throughout, and as it was tested at different stages of fabrication, with similar results, there can be no doubt about its quality. This steel was first tested in the form of the usual ¾-inch rd. rolled rods from test ingots; then strips were cut from the bars after rolling, turned to standard shape of test pieces, and again tested. As many of the bars were partly punched they required annealing, and to determine the effect of this reheating, standard test pieces

were obtained as before and then annealed with regular bars, in order to produce in them the same effect as in the bars, and again tested. The results obtained, and given below, show the quality of the material very plainly. The tests made also show with what absolute certainty and regularity steel can be made by the Bessemer process in the hands of willing and careful supervision.

Out of a total of 113 blows, giving about 900 tons of rolled steel, there were only 11 blows rejected, not as inferior steel, but merely as giving lower results, therefore apt to produce lack of uniform wear of the rack teeth in course of time. Of these 11 blows not used, four were made one day and four others another, leaving but three blows rejected at odd times in four months during which the steel was made. In both cases, when these several blows were laid aside, the steel was made after the converters had been running on different material for some time previous to the time of attempting to make this material, showing that if the same material had been made without intermission, there would have been only three blows laid aside out of a total of 113. Considering the narrow limits between which this material was selected, this is an admirable record, and reflects great credit on the Bessemer department of the Cambria Iron Company. A few single blows gave the following low results:

Tenacity, 69,600 pounds; 25.3 per cent. elongation in 8 inches, and 46.6 per cent. reduction, and a few others gave the following high results:

Tenacity, 75,830; 24.2 per cent. elongation in 8 inches, and 51.2 per cent. reduction.

The average of the great number of tests was between tenacity of 70–72,500 pounds, 24–26 per cent. elongation, and 46–50 per cent. reduction, with very slight variations.

The average results for test pieces cut from rolled bars were: Tenacity, 68,840–72,680; 26.4 to 27.9 per cent. elongation in 8 inches, 58–58.4 per cent. reduction.

The average results for test pieces as above, but annealed, same as many bars, were as follows:

Tenacity, 67,880–72,680 pounds; 25.7–28.1 per cent. elongation in 8 inches, and 50.3–60.1 per cent. reduction.

The results of tests of chair material are also very good, but not as uniform as the above, although the steel is somewhat easier to make; they were as follows:

Tenacity, 59,720–65,270 pounds; 20.5–30 per cent. elongation in 8 inches, and 51.4–60.9 per cent. of reduction of area.

The rack bars are uniform in section, only varying in thickness, being bars with rounded corners; the teeth are 2 inches high, and spaced to 4.706 inches pitch, being located or gauged from the centre bolt holes in the bars.

The process of making the bars, in order to cut the teeth absolutely uniform with the slightest possible amount of error, was a tedious one, as no special milling tools or gear cutters could have been provided in the short time available, and the prescribed limit of error was very small.

The specifications for workmanship in relation to the bars were as follows:

"The bars must be straight in every direction; the teeth, particularly, must be in a perfectly straight line, and their dressed working faces must be accurately at right angles to the bar.

"The thickness of the bar, and especially of the teeth, must be uniform throughout, and shall in no case vary more than 1 per cent. under or 2 per cent. over that called for by the drawings.

"The shape and pitch of all teeth shall be according to template to be furnished, and shall be accurate. The edges shall be smooth, and all burrs must be filed off.

"The admissible error for a single pitch division may be $\pm \frac{1}{50}$th of an inch, but the aggregate of all errors in one single rack bar shall not exceed $\pm \frac{1}{25}$th of an inch. The error in the total length of the bar shall also not exceed $\pm \frac{1}{60}$th of an inch."

In order to conform to such difficult specifications and attain the necessary accuracy, it became imperative to devise methods which would produce absolutely uniform results, and at the same

time avoid possible errors due to repeated measuring or personal equation of different mechanics. Jigs were therefore devised, which entirely avoided the possibility of shifting, and made the execution of the work so simple that boys and laborers could take the place of machinists.

The method adopted and carried out was the following:

As the long bars came from the rolls they were straightened and inspected for surface defects and correctness of shape.

Then these bars were sawed to the correct length of 84 inches; after which these short pieces were rectified to a straight edge.

Now a jig template was placed on a bar, with studs bearing against one end, and others bearing against the guiding edge. In this jig template hardened steel bushings were secured in a most careful and correct manner to guide the twist drills invariably used in locating and cutting all holes that were to be put through the bars.

Then three or four bars, according to thickness, were packed rigidly together in three small, stiff, U-shaped yokes, the two outer sides of which were planed true and square to each other, on which these packages of bars could be moved freely on the machine table, and would prove the absolute rectification of the bars, any distortion causing rocking of the yokes on the table. The upper of these bars had all holes marked off from the jig-plate. As the bars were to fit and bear upon the chairs accurately, the lower or bearing edge of the bars was assumed as the guiding edge or base for all measurements. Hence this edge was brought to bear against one side of the yokes and wedges driven in on the other to secure them.

By thus merely marking but one bar in three or four sufficiently to guide the drills correctly, the wear on the hardened bushings in the jig template was reduced to a minimum. One skilled mechanic did this marking off, while a lot of boys packed the bars and drilled the holes through these packages of bars on a large multiple gang drill, with three or four drills on each package going at the same time, and three or four packages being drilled at once.

This mechanic also watched the gang drill and the boys, and could easily keep up with his own special work at the same time, and keeping a record of the work done as well. Each bar had thirty-eight holes drilled through it—four to bolt the bars to the chairs and thirty-four clearance holes, two at the root of each tooth. Such a jig template avoided the use of wrong-sized drills, as none but the correct size would fit the hardened bushings. The multiple gang drill, having fifteen drill spindles, was speeded up so that holes varying from $\frac{15}{16}$ to $1\frac{1}{16}$ inches diameter were drilled $3\frac{3}{4}$ inches deep in 7 minutes, or 1 inch of steel drilled in 1.87 minutes, working 22 hours per day, or a total of 138 per week, continuously. After these holes had all been drilled the bundles were broken, burrs cleaned off, and the bars carried to shaping machines and planers and packed together on edge in lots of ten, by driving a neatly-fitting pin through one of the middle bolt holes. This allowed all bars to rest uniformly on their lower edges on the machine tables, and smaller bolts were put through the end holes to hold the ends of bars together. The teeth were then roughed out by slotting a groove $\frac{1}{4}$-inch wide down from the top of the tooth into the clearance holes at the root, leaving a block of metal standing in the gap. This block of metal was then broken out by one sharp blow of a small hammer, and the bars were ready to be put on the finishing planers.

For finishing correctly a jig-box had been cast which had a correct counterpart of the racks on each side carefully cut to a gauge; the ends of this box were carefully cut to correct length of bars, and in order to set the bars correctly in the boxes a hole was provided in them, passing through the sides, through which, and the proper bolt-holes in the bars, a neat fitting pin was again driven. The bars were then closely packed by means of set screws on one side and straps with set screws across the top of the box. A tool of the correct shape of the gap between teeth was then ground down accurately and fed by the tool holder into the gaps in the edges of the jigs; after again raising the tools above the bars the planer was

started and then the tool fed down slowly to cut the gaps to match the jigs. After then trimming the ends of bars to length they were removed to an inspection table, preparatory to painting and shipping.

By this method very satisfactory results were obtained.

The chairs against which the rack-bars were bolted have a centre rib $1\frac{5}{8}$ inches thick, running down into a shoulder on each side, to give perfect bearing to the lower edge of the bars, and sloping down into a foot or plate one edge of which is turned down at right angles to bear against the upper face of the ties. Two 1-inch wood srcews pass through the foot into the tie, and further secure the chair. A T-iron is driven into the centre web from below and also bears under the shoulders and on the tie, thus making a very rigid chair. This centre T is in some cases longer and then riveted to the box that bears against the strut-anchor. The rack-bar bolts pass through the rib of chair and through the vertical flange of the T driven into it. The conditions prescribed for the chairs were that the outer sides of the centre rib be parallel to each other; that these be truly at right angles to the upper surface of the shoulders, on which the bars rest, and that the bolt holes be neat and absolutely correct in position. The fillets from rib to shoulder were not to exceed $\frac{1}{8}$-inch radius, otherwise the bars would not fit. All chairs were made alike as regards shape and material, only the size of bolt holes were different in diameter, to match those in the different sizes of bars.

The steel was rolled into $\frac{9}{16}$-inch plates 8 inches wide, which were sheared into 20-inch lengths.

These plates were notched 1-inch deep on one edge, which left two lugs, one on each end, stand out; then they were heated and finished by three blows of a steam hammer in as many dies. The first operation turned up the rib in V form, and turned down the lugs; the second made the rib vertical, and the third drove in the T before mentioned, and gave the final correct shape of the rib by slightly upsetting, and set the lugs properly.

The bolt-holes were then drilled by twist drills, fed through a jig box with hardened steel bushings and an end lug for position. This jig box was of U shape, fitting snugly over the centre rib, and was forced against the bearing shoulders by a cam lever pivoted on a bracket plate against which the chair was placed. After one hole had been drilled a neat fitting pin was driven into it, thus avoiding any possibility of shifting, as the chair was not loosened in the jig until the second hole had been finished.

Wherever the chairs were anchored neatly fitting bolts were used to avoid any possibility of slip or motion.

All bars were spliced by extra plates on the outside ½-inch or ⅜ inches thick and 2½ inches wide, as the bars were 1 inch or over, or under that thickness.

In order to test the accuracy of the bars and chairs, male and female templates of extreme accuracy were used and tried on every batch of bars on both sides. For this purpose the bars in batches were placed on edge on skids, leveled up carefully, and then by use of templates and the eyes and rule were examined in detail. The character of the material was again inspected and all piped bars were rejected; piping was clearly developed by finishing the teeth.

In order to hurry the work as much as possible, another method was adopted in making the ⅞-inch and 1-inch bars; but the results showed what was to have been expected—namely, that the most accurate methods are the best, quickest and cheapest, or, in other words, that drilling is better than punching, technically and commercially.

A large punching machine was fitted up with punch and dies and the proper spacing stop, and the gaps between teeth were then punched out. The amount of material which it was found necessary to leave for finishing the faces of teeth was found to be just double that required in the first method. The punching bent each bar to a vers-sin of about 18 inches, according to thickness, and this curve had to be removed without injuring the bars or material. Then the end gap could not well be punched because of extreme disturbance

or actual rupture of bar. Annealing became necessary to bring the metal back to its original condition. Then the extreme curvature required hot straightening and afterward cold straightening to rectify the bars entirely. Moreover, a single mishap in one of the sixteen gaps or punchings made the bar useless. Furthermore, slight irregularities in spacing in the punch caused the rejection of many bars, as the teeth could not be finished for lack of material. It also became necessary to plane the ends of all these punched bars as the punching and straightening stretched them considerably.

The drilling, however, was reduced to that of the four chair-bolt holes instead of 38 holes.

From this it can readily be seen that the number of processes and precautions necessarily taken to obtain fair results, were very much increased when punching the bars, and that the time consumed by these made the total much greater than when drilling. Moreover, the quality of bars as regards both finish and accuracy was very much inferior to that obtained by the first method, so that it was agreed between the manufacturer and the engineers that there was neither economy in time or money and that the general results of accuracy and reliability were much less satisfactory when punching the bars instead of drilling and shaping, and that that method would not again be resorted to in future work. It must also be here stated that it required much greater care and more constant supervision on the part of shop foremen to obtain satisfactory results, and also higher priced labor to secure these.

A few words about the engines used on the Pikes Peak Road may not be out of place here, and the principal dimensions are given as follows:

They were built at the Baldwin Locomotive Works, Philadelphia, and are tank engines, with tanks on the side above the frame. The coal is carried in a box at the back of the cab. There are two frames for the engine, both bar type. The main outside carrying frame has channel iron at the rear, the back horn block being made of a plate riveted to the channel iron at back of frame. The inner

or secondary frame carries the main driving pinions and cranks with brake discs and band brakes, and must resist the entire down hill thrust. The rear truck swings on a radius bar, and the main wheels running on the rails, which are usually the drivers, are, in this case, merely carrying wheels.

Gauge	4 ft. 8½ in.
Cylinders	17×20 in.
Drivers	22.468 in.
Total wheelbase	11 ft. 8½ in.
Driving "	4 ft. 1½ in.
Weight, total	53,600 lbs.
" on drivers	50,700 lbs.
Boiler, diameter	44 in.
No. of tubes	176.
Diam. of tubes	1½ in.
Length of tubes	7 ft. 6 in.
Firebox, length	48 in.
" width	59⅜ in.
Firebox, depth,	F. 46¼ in., B. 40⅝ in.
Water space,	F. 3½ in., S. & B. 2½ in.
Staying	Radial.
Truck wheels, diam.	25½ in.
Truck Journals	4×6 in.
Driving wheel centres	15¾ in.
Main axle journals	6×7 in.
Driv. axle journals	7½×4¼ in.
Support axle journals	6×6 in.
Carrying wheels, diam.	25½ in.
Carrying journals	4½×6 in.

These engines weigh about 56,000 pounds, and the tanks hold 700 gallons of water.

In order to avoid possibility of the pinions leaving the racks on curves they are made 2⅝ inches face while the thickest bars are only 1¼ inches. These pinions are secured to their axles or shafts, which carry the drums for the band brakes, and thus the steam cylinders can and are intended to be made to furnish the brake power, although the bands are at the same time controlled by hand-power from the engine cab. There are three pairs or six pinions coupled with three pairs or six wheels and brake bands, each being singly sufficient to hold engine and cars on a 25 per cent grade; but even the service of all of these brakes are only required in case of emergency, as the le Chatelier brakes fitted to the steam cylinders are the only ones to be used in descending, they being fully able to check the descent on down grades. Each car is also fitted with two pairs or four pinions, each with a hand brake sufficient to stop and hold a loaded car on a 25 per cent. grade. The cars not being coupled to the engine, and being always on the upper side of it, the

latter might run away and the cars would be stopped readily by the hand brakes with which they are provided. This road had been entirely completed about October 20, 1890, and preparations are now being made to open the road for regular passenger traffic as soon as the season permits. The road has thus far been used mainly for carrying materials and more perfectly ballasting the road bed, but in regular work it will be devoted almost exclusively to passenger service.

AN INTERESTING EXPERIMENT WITH A HOT-AIR ENGINE.

BY G. M. BOND AND W. P. PARSONS, '80.

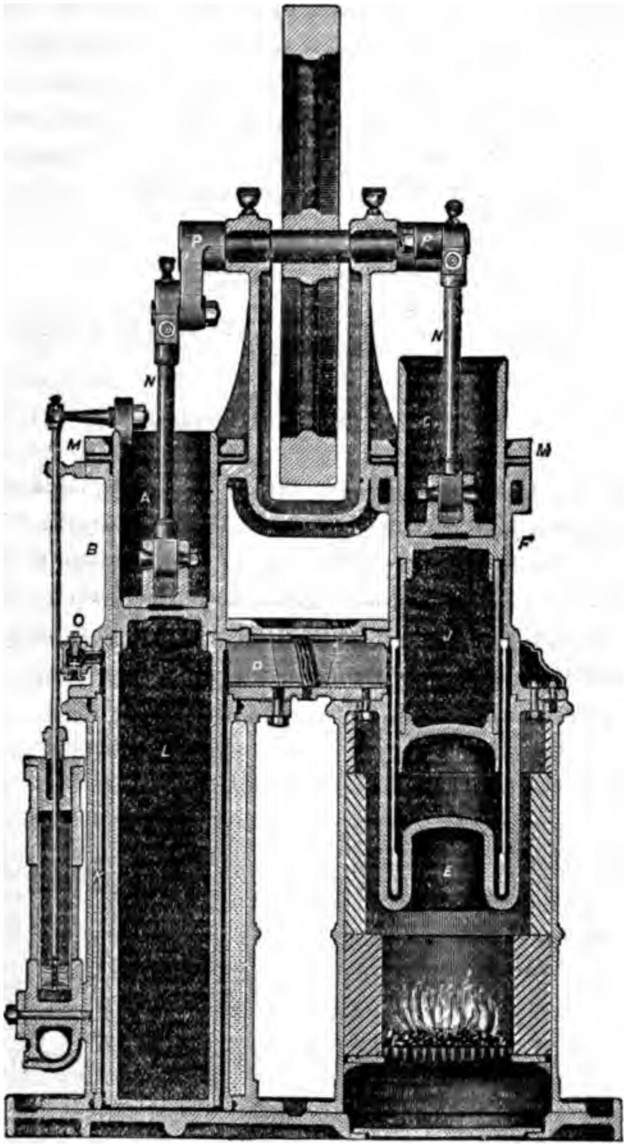
DURING the spring of 1880 the writers had placed at their disposal a Rider Hot-Air Engine, for the purpose of determining by direct measurement the various temperatures undergone by the air used in the engine to produce motive power. A cross-section of the engine is shown in the accompanying engraving. The dimensions were as follows :

Diameter of power piston	6¼ inches.
" " pump "	6¼ "
Stroke of power piston	9½ "
" " pump "	8¼ "
Angle between power and pump cranks	95 degrees.
Area of grate	0.45 square feet.
Area of heating surface	3.5 " "
Area of regenerator surface	0.9 " "

The engine was intended to develop sufficient power to pump 1,000 gallons per hour against 50 feet of head. Its ordinary speed is 124 revolutions per minute. The changes undergone by the air in driving such an engine are briefly as follows :

Conceive the power piston to be at the bottom of its stroke.

The pump piston is then at about half-stroke. The greater portion of the air in the engine is then occupying the space beneath


P
P
N
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the pump piston. The motion of the engine causes the pump piston to move downward as the power piston moves upward. The displacement of the former being much more rapid than the latter, owing to the positions of the cranks, the air is transferred so quickly through the regenerator and into contact with the furnace-heating surfaces that, practically, its pressure is maintained at the highest limit during the greater part of the downward movement of the pump piston. As the latter rises through the first half of its upstroke the displacement of the power piston becomes relatively the greatest, and the action of the air may be considered as an expansion at the higher limit of temperature. Similarly, during the down stroke of the power piston and the return of the pump piston to its initial position, the majority of the air is transferred to the pump side of the engine, and its action is equivalent to compression at the constant minimum pressure of the cycle, for part of the stroke, and compression at the constant minimum temperature of the cycle for the remainder of the stroke—*i. e.:* the temperature imposed upon the air below the pump piston by the cooling influence of water, which is circulated through the space.

During the downward stroke of the pump piston, the pressure of the air is always greater than during its upstroke.

Consequently, the net indicated work of the motor is found by subtracting the power shown by the pump indicator card, from that shown by the power indicator card. A complete measurement of the temperatures, assumed by the air, at the various portions of its cycle of changes, required the determination of the temperature beneath the power piston, and at the entrance to and exit from the regenerator—at the several positions of the cranks corresponding to the positions of the pistons discussed in the above description of the cycle of the engine. The clearance spaces within the engine would not permit of the use of any form of thermometer occupying as much space as ordinary mercurial thermometers, and furthermore the rapidity of the changes of temperature, at 124 revolutions per minute, made the use of such thermometers impracticable. The

means of measuring temperature adopted, was, therefore, that of noting the change of electrical resistance in a fine platinum wire, using the formulæ of Dr. Siemens for the calculation of temperatures from the changes of resistance. Holes were drilled through the furnace and copper wires inserted therein, whose terminals were connected by a fine platinum wire. The necessary insulation was provided by a suitable joint of pipe clay and asbestos. By affixing a commutator device upon the crank shaft, a galvanometer could be applied to determine the resistance of a platinum wire lodged in the furnace at any point of the piston travel. A similar arrangement was applied at the extremities of the regenerator. Indicator cards were taken from both the pump and power cylinders, while a prony brake was applied to the fly-wheel, so as to determine the net work and provide a constant load against which the engine could work. Measurements were also made of the amount of heat abstracted by the circulation of water around the power piston. The results of the experiments were as follows:

INDICATOR CARDS.

When the motion of the indicator drum was taken from the power piston for both the cards from the pump and the power cylinders, the diagrams oblained were as per Fig. 1; the outline which

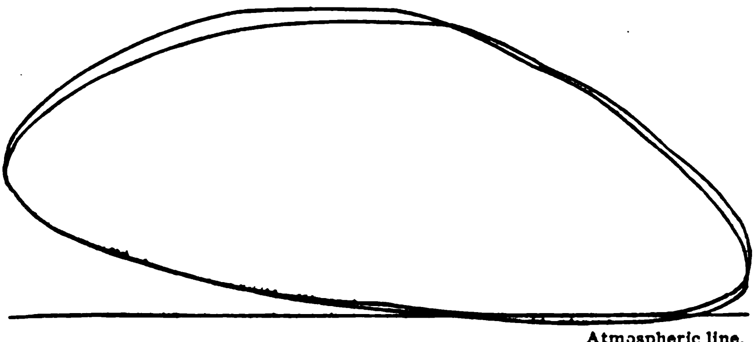


FIG. 1. Scale 10 lbs. = 1 in.

dips below the atmospheric line belongs to the pump cylinder, and the other outline to the power cylinder. The slight differences of pressure

shown by these diagrams indicates that there is practically no loss of pressure due to the friction of the passages traversed by the air in passing between the two cylinders. The lowest pressure of the air is practically equal to the atmosphere, a check-valve being provided which admits atmospheric air whenever leakage so reduces the charge in the machine, that the minimum pressure tends to fall

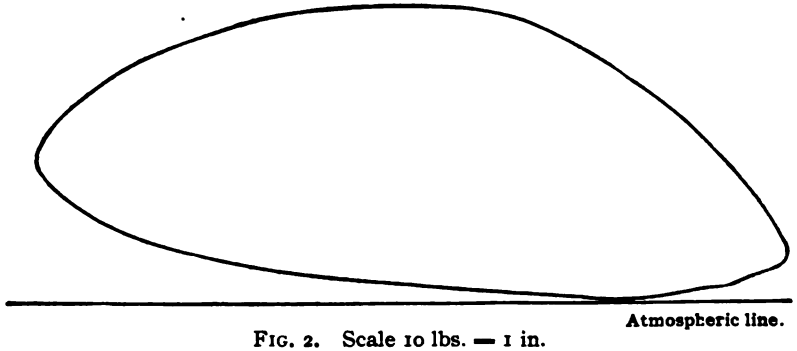


FIG. 2. Scale 10 lbs. — 1 in.

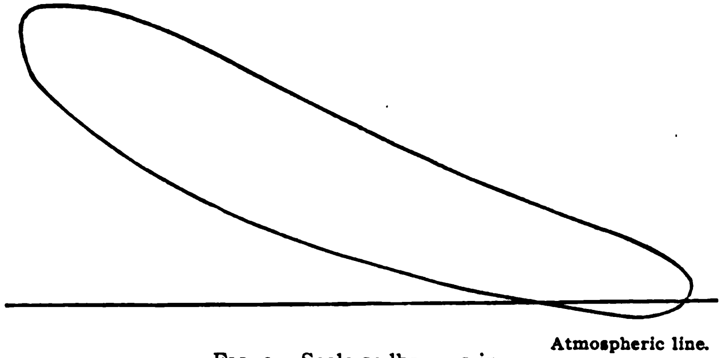


FIG. 3. Scale 10 lbs. — 1 in.

below the atmosphere. Figure 2 shows the power card isolated from the pump card, and Fig. 3 shows the pump card when the indicator drum motion is derived from the pump piston. Computations of power from cards Figs. 2 and 3, gave results as follows :

Indicated work per stroke or revolution power piston.	360.76 ft. lbs.
" " " " " " pump " .	171.57 "
Difference or indicated work per revolution.........	189.19 "
Indicated power to run engine unloaded...........	93.44 "

PRONY BRAKE MEASUREMENT.

Work per revolution, engine loaded .... 94.25 ft. lbs.

ABSOLUTE TEMPERATURES, FAHRENHEIT.

Position of Power Crank.	Temp. under Power Piston.	Temperature in Regenerator. Hot End.	Cold End.
0° (bottom of stroke)	987°	792°	
90° (from bottom)...........	882°	621°	549°
270° (from bottom position)...	844°	761°	590°

A fair conclusion from the above figures is, that the average temperature beneath the power piston is about 900 degrees absolute, or about 440 degrees on the ordinary Fahrenheit scale, and that the temperature at the entrance to the regenerator averages about 750 degrees, or about 290 degrees on the ordinary Fahrenheit scale. And, if we conceive that that part of the passage traversed by the air on its way from the furnace to the regenerator acts as part of the regenerator, it may be assumed that the regenerative effect commences at a temperature of about 815 degrees absolute, Fahrenheit. It then follows that about 40 degees of temperature are lost by the air through radiation, etc., which amounts to about 17 per cent. of the heat abstracted by the regenerator, which is the form of expression used in Rankine's steam engine in characterizing this kind of waste in air engines.

THEORETICAL DEDUCTIONS.

Assuming the cycle of changes undergone by the air to be as described above, that is, that the card of the working air is bounded by two isothermal lines, and two lines of constant pressure, we have the work represented by the difference of the theoretical indicator cards of the power and pump cylinders equal to

$$W = \frac{P_0 V_0}{T_0} (T_1 - T_0) \text{ hyp. log} \frac{P_1}{P_0},$$

in which T_1 and T_0 are the temperatures at the entrance and exit from the regenerator, V_0 is the volume of the working air at the lowest pressure, at the instant when compression along the inner isothermal line begins, and P_1 and P_0 are the minimum and maxi-

mum pressures. The value of V_0 was .28 cubic feet. Substituting this, together with the temperatures given above, and the pressures shown by the indicator card, we find the theoretical work per revolution to be 185 foot-pounds. This is within 5 per cent. of that determined from the actual indicator cards. The indicator card representing this work is shown in Fig. 4. This card is the difference between the power card and the pump card. It corresponds to what is called the indicator card of the working air in Rankine's treatment of air-engines, and is obtained by combining Figs. 2

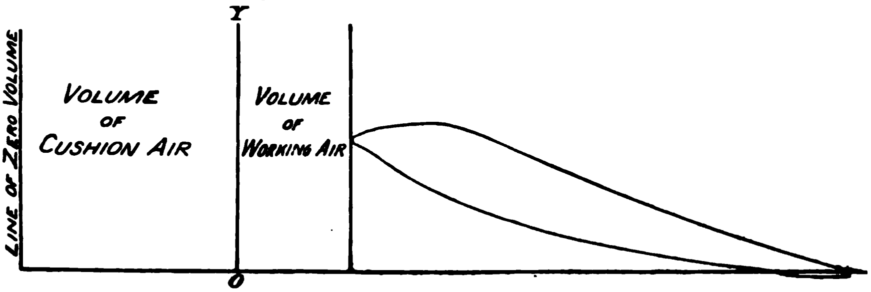


FIG. 4. Scale 10 lbs. — 1 in. Atmospheric line

and 3 so as to eliminate the effect of the cushioned air. The theoretical amount of heat expended is

$$H_1 = \frac{P_0 V_0}{T_0} T_1 \log. \frac{P_1}{P_0}$$

or 639 foot-pounds per revolution, due to heating the air during its isothermal expansion, and 0.17 $(T_1 - T_2) \times$ specific heat at const. pressure $\times$ weight of V_0, or 140 foot-pounds, are due to regenerator wastes. The total expenditure per revolution is, therefore, 780 foot-pounds. This makes the efficiency of fluid 24 per cent. The theoretical heat abstracted per revolution during compression along the isothermo is

$$H_2 = \frac{P_0 V_0}{\quad} \log. \frac{P_1}{P_0} \text{ or 594 foot-pounds.}$$

The actual abstraction, as measured, was 607 foot-pounds. The discrepancy is, therefore, only about 3 per cent. The engine consumed about two pounds of coal per hour. Assuming the combustion of each pound to create 10,000,000 foot-pounds, at 124

revolutions per minute, and 189 foot-pounds per revolution of indicated power, it follows that the combined efficiency of furnace and fluid is about 7 per cent. This makes the efficiency of the furnace alone about 28 per cent. The effective work, taken at 95 foot-pounds per revolution, represents an amount of power equivalent to pumping about 1,400 gallons of water per hour against 50 feet of head, which is about one-third greater capacity than the rating of the motor at the hands of its present manufacturers.

Figure 5 is the card given by the engine, with the angles between the cranks considerably over 95 degrees. It represents

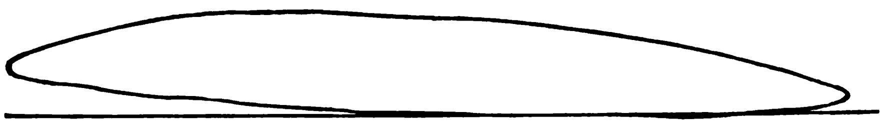


FIG. 5. Scale 10 lbs. = 1 in. Atmospheric line.

the power card reduced by the area of the pump card, or the net effective work corresponding to that shown in Fig. 4 for the normal conditions of cranks at 95 degrees.

INFLUENCE OF A RECEIVER JACKET ON THE INDICATOR CARDS OF A COMPOUND ENGINE.

BY PROF. D. S. JACOBUS.

THE engine tested was built by the Hewes and Phillips Company, and now furnishes power for their works at Newark, N. J. It is a compound engine of the Corliss type, with both pistons attached to the same rod.

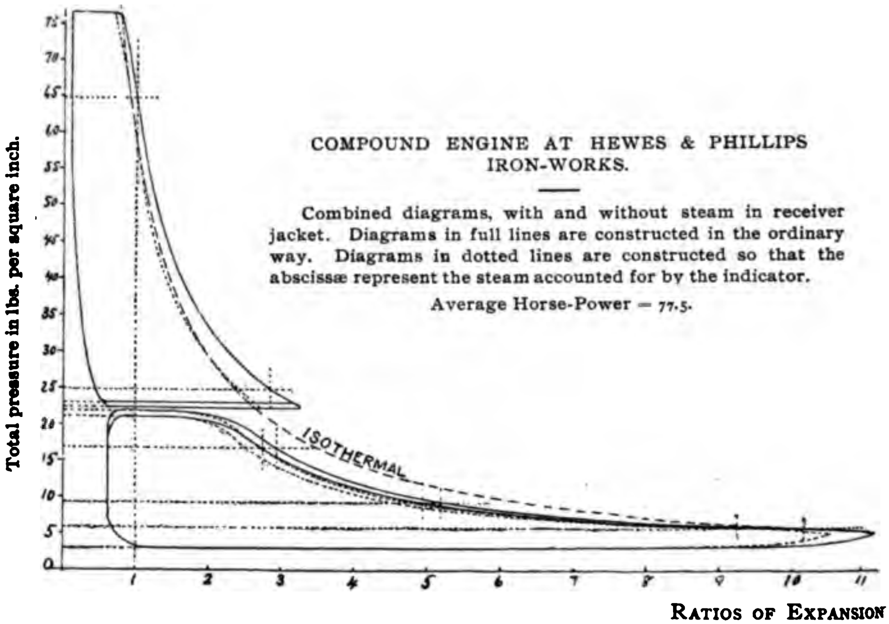
There are no jackets on either of the cylinders, whereas the receiver is jacketed with steam at full boiler pressure.

The dimensions are as follows:

Bore of High Pressure Cylinder in inches	12
" Low " " "	22
Stroke in inches	36
Diameter of High Pressure and Low Pressure Piston Rods	$2\frac{3}{16}$
" " Second Low Pressure Piston Rod	$3\frac{1}{8}$
Clearance in per cent. of net volume H. P. Cyl	3.2
" " " L. P. "	6.1
Surface of Receiver acted on by the Jacket Steam in square feet	30.

The object of the test was to determine the form of the indicator cards, with and without steam in the jacket of the receiver.

Indicator cards were taken, under both sets of conditions, during the afternoon of one day and also on the following day. As the work done by the engine was of a variable nature it was not possible to compare all the cards; two sets were, therefore, selected, which, with a given setting of the valve motion, gave approximately the same cut-off in the high pressure cylinder.



From these the following facts are demonstrated:

1. The expansion line of the low pressure card is raised by the action of the steam in the receiver so that the mean effective pressure during expansion is increased about one-half a pound per square inch, which is approximately 7 per cent. of the whole.

2. The pressure in the receiver is increased about 4 per cent.

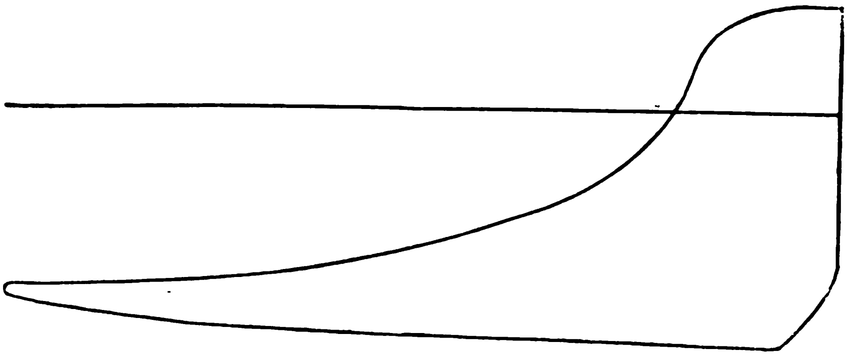
3. The steam at release in the high pressure cylinder, accounted for at cut-off in the low pressure cylinder, was 64.6 per cent. with no steam in the jackets, and 71.0 per cent. with steam in

the jackets. As no opportunity was offered to measure the steam condensed in the jacket of the receiver the economy of the jacket cannot be deduced.

The indicator cards and combined diagrams are represented in Fig. 1. The combined diagrams, in full lines, are constructed in the ordinary manner by laying off the length of the cards in proportion to the relative net volumes of the cylinders.

The diagrams, in dotted lines, are laid off so that the abscissæ of the curves are proportional to the weight of steam calculated from the indicator cards.

The combined diagrams show that there is considerable condensation during admission to the low pressure cylinder; this feature



Low Pressure Cylinder. Scale 10.

is common to all compound engines in which the steam is cut off at an early point of the stroke in the low pressure cylinder.

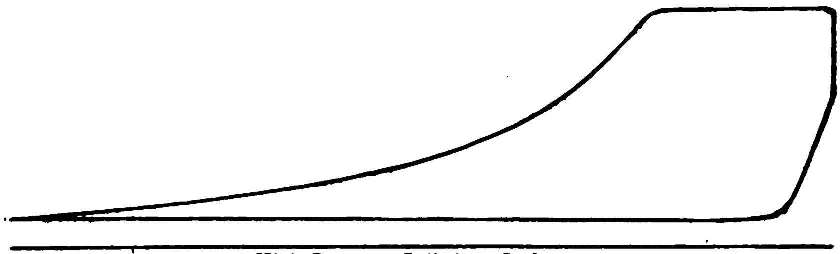
In taking the indicator diagrams a very exact reducing motion belonging to the Hewes and Phillips Company was employed. This motion has been described in a paper presented to the American Society of Mechanical Engineers by Mr. A. W. Jacobi.*

It consists essentially of an endless wire cord run over pulleys in order to reach the indicators. The wire is adjusted so that it has considerable initial tension. Motion is imparted to the wire cord by means of a pantograph. We are indebted to the chief draughtsman

*Transactions of the American Society of Mechanical Engineers. Vol. X., p. 586.

of the company, Mr. J. H. Hortsmann, for kindly arranging the motion for us, and for assisting in taking many of the cards.

The data observed during the time that the particular sets of cards were taken is given in Table I. Tables II. and III. give the measurements obtained from the cards, and show in detail the calculations made to determine the ratios of expansion.



High Pressure Cylinder. Scale 50.

Table IV. contains the data and calculations necessary to obtain the steam per hour per horse-power and per cents of steam accounted for at various points in the stroke.

TABLE I.

Data Observed During Time that Indicator Cards were Taken.

CONDITIONS.	Number of Set of Cards.	Pressure in Pounds per Square Inch. Boiler.	Pressure in Pounds per Square Inch. Receiver.	Vacuum in Inches of Mercury.	Revolutions of Engine per Minute.	Barometer in Inches of Mercury.
No Steam in Jacket of Receiver.	12	69.0	6.3	26.0	80.5	30.12
	13	68.0	6.0	26.0	80.5	30.12
	14	68.5	6.0	26.0	80.5	30.11
	17	69.0	5.8	26.2	80.5	30.11
	19	69.0	5.6	26.2	80.5	30.10
Average.....	......	68.7	5.9	26.1	80.5	30.11
Steam at Full Boiler Pressure in Jacket of Receiver.........	101	69.0	7.0	26.2	80.5	29.66
	105	68.5	6.5	26.1	80.5	29.65
	106	68.0	6.5	26.1	80.5	29.64
	108	69.0	6.8	26.1	80.5	29.64
	109	68.5	6.5	26.2	80.5	29.64
Average	......	68.6	6.7	26.1	80.5	29.65

TABLE II.

Indicator Cards taken February 20, 1891. No Steam in Jacket of Receiver.

No. of Set of Indicator Cards.	Lengths Measured on Indicator Cards. Of Card not including Clearance.		Lengths Measured on Indicator Cards. To Points in Expansion Line, including Clearance. Average of Values for Both Ends of Cylinder. Near Point of Cut-off.		Near Middle of Expansion Curve.	Near Point of Release.		Ratio of Lengths, including Clearance to Lengths of Indicator Cards. Near Point of Cut-off.		Near Middle of Expansion Curve.	Near Point of Release.		Ratios of Expansion. Near Point of Cut-off.	Near Middle of Expansion Curve.	Near Point of Release.	
	H. P.	L. P.	H. P.	L. P.	L. P.	H. P.	L. P.	H. P.	L. P.	L. P.	H. P.	L. P.	L. P.	L. P.	H. P.	L. P.
12	4.31	4.45	1.32	1.11	2.01	3.79	3.73	.306	.249	.452	.879	.838	2.73	4.95	2.87	9.17
13	4.33	4.44	1.33	1.13	2.04	3.85	3.86	.307	.254	.460	.889	.872	2.77	5.02	2.90	9.51
14	4.32	4.44	1.29	1.08	1.91	3.71	3.62	.299	.243	.430	.859	.815	2.72	4.82	2.86	9.13
17	4.32	4.44	1.32	1.11	1.98	3.80	3.65	.306	.250	.446	.880	.822	2.74	4.89	2.88	9.00
19	4.34	4.44	1.26	1.07	1.94	3.65	3.62	.290	.241	.437	.841	.815	2.78	5.05	2.90	9.42
Average quantities.								.302	.247	.445	.870	.832	2.75	4.95	2.88	9.24

In the above table the absolute pressures in pounds per square inch, employed in laying-off points in the expansion lines, are as follows:

Near point of cut-off, H. P. = 64.8; L. P. = 16.8. Near middle of expansion curve, L. P. 9.3. Near point of Release, H. P. = 24.8; L. P. = 5.8.

TABLE III.

Indicator Cards taken February 21, 1891. Steam in Jacket of Receiver.

No. of Set of Indicator Cards.	Lengths Measured on Indicator Cards.							Ratio of Lengths, including Clearance, to Lengths of Indicator Cards.					Ratios of Expansion.			
	Of Card, not Including Clearance.		To Points in Expansion Line, including Clearance. Average of Values for both ends of Cylinder.													
			Near Point of Cut-off.		Near Middle of Expansion Curve.	Near Point of Release.		Near Point of Cut-off.		Near Middle of Expansion Curve.	Near Point of Release.		Near Point of Cut-off.	Near Middle of Expansion Curve.	Near Point of Release.	
	H. P.	L. P.	H. P.	L. P.	L. P.	H. P.	L. P.	H. P.	L. P.	L. P.	H. P.	L. P.	L. P.	L. P.	H. P.	L. P.
101	4.31	4.44	1.38	1.25	2.35	4.00	4.26	.320	.281	.529	.928	.960	2.94	5.54	2.90	10.05
105	4.31	4.42	1.21	1.11	2.07	3.51	3.87	.281	.251	.468	.814	.876	2.99	5.58	2.90	10.44
106	4.31	4.42	1.30	1.18	2.16	3.73	4.02	.302	.267	.488	.865	.909	2.96	5.41	2.86	10.08
108	4.30	4.44	1.31	1.20	2.17	3.76	4.14	.305	.270	.489	.874	.932	2.99	5.37	2.86	10.24
109	4.30	4.43	1.46	1.29	2.40	4.19	4.51	.340	.291	.542	.974	1.018	2.87	5.34	2.86	10.03
Average quantities.								.310	.272	.503	.891	.939	2.95	5.45	2.88	10.17

In the above table the pressures used in laying off points in the expansion lines are the same as in Table II.

TABLE IV.

Calculation of Steam per Hour per Horse-power and of Re-evaporation During Expansion.

Character of Test.	High and Low Pressure Cylinder.	Ratio of Volume (including clearance) to Volume swept through by Piston.			Absolute Pressure in Pounds per Square Inch.			Density of Steam in Pounds per Cubic Foot.			A × D − C × F.	B × E − C × F.	Re-evaporation during Expansion in per cent. of Steam Accounted for by Card, at Cut-off.	Mean Effective Pressure in Pounds per Square Inch.	Steam per Hour per Horse-Power.		Per cent. of Steam at Release of High Pressure Cylinder, Accounted for at Cut-off in Low Pressure Cylinder.	Per cent. of Steam at Cut-off of High Pressure Cylinder, Accounted for at Release of Low Pressure Cylinder.
		Near Point of Cut-off.	Near Point of Release.	Clearance.	Near Point of Cut-off.	Near Point of Release.	At End of Compression.	Near Point of Cut-off.	Near Point of Release.	At End of Compression.					Near Cut-off.	Near Release.		
		A	B	C				D	E	F								
No Steam in Jacket of Receiver.	H	.302	.870	.032	64.8	24.8	55.6	.1534	.0620	.1327	.04208	.04969	18.1	23.2	12.47	14.72	64.6	96.3
	L	.247	.832	.061	16.8	5.8	6.3	.0430	.0158	.0171	.00958	.01210	26.3	6.93	9.51	12.01		
With Steam in Jacket of Receiver.	H	.310	.891	.032	64.8	24.8	58.5	.1534	.0620	.1392	.04310	.05079	17.8	22.0	12.17	14.34	71.0	108.0
	L	.272	.939	.061	16.8	5.8	5.6	.0430	.0158	.0153	.01076	.01390	29.2	7.97	10.18	13.14		

SOME RECENT DEVELOPMENTS IN THE THEORY OF MAGNETISM.

BY THORBURN REID, M. E., '88.

THE rapid growth in the use of apparatus employing alternating currents of electricity, which has taken place in the last two or three years, has given a decided impetus to study and research into the laws and phenomena of magnetism, especially as they are evidenced in the behavior of iron and steel when under magnetic stress produced by the lines of force of an electric current. The imperative necessity of a clearer and more intimate knowledge of the laws of magnetism, which has been laid upon us as a result of the commercial use of apparatus using alternating currents, will be shown later, after we have briefly sketched the developments which have lately been made in magnetic theory by means of research and experiment.

The first long step in advance in the development of the modern theory of magnetism may, without doubt, be accredited to Ewing, who, in a paper read before the Royal Society, communicated the results of a long series of experiments on the magnetic behavior of metals, and gave to the scientific world the word "Hysteresis," together with a clear exposition of the phenomena denoted by it.

It has been well known for a long time that the permeability of iron and steel decreased as the magnetic induction (or the number of lines of force per square unit) increased. The iron was said to approach saturation, as though there were a limit to the amount of magnetism that it could hold, and the more nearly this limit was approached the harder was it to force any more magnetism in. An unfortunate perversion of the meaning of this term saturation has sprung up lately, and I am even inclined to doubt the propriety of using the term at all in this connection on account of the vagueness of its definition. The saturation point is said to be on the "knee" of the saturation curve (*A*, Fig. 1). Unfortunately just where this

knee begins and ends cannot be easily defined, and in many cases, always in cast iron, there is no such knee at all, the curve sweeping gently around almost from the origin. Figure 1 shows a typical wrought-iron saturation curve, and the knee is there very decided, but Fig. 2, which is a curve of mild steel of rather poor magnetic quality, the position of the knee is entirely indefinite. The curves of cast iron resemble very closely that shown in Fig. 2.

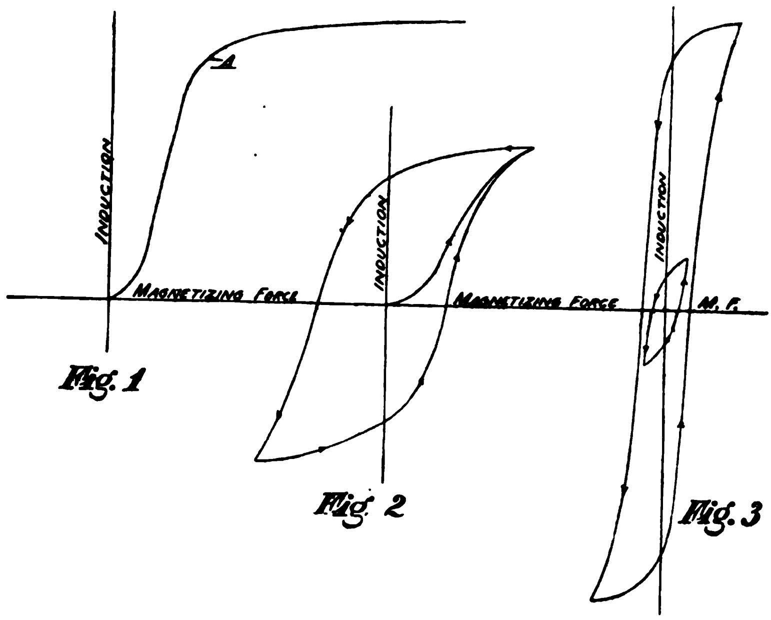


Fig. 1 Fig. 2 Fig. 3

Another common mistake is that of supposing the permeability constant until the so-called knee is reached. As a matter of fact the permeability is never constant, and only approximately so for a very short portion of the curve below the knee. The iron is also commonly said to approach saturation after the knee is passed, which statement evidently supposes a different meaning for the word. For my part I see no well-defined need for the word at all, and it is certainly unwise to use it if different people give it different meanings. To speak of iron as being saturated conveys to the ordinary electrician very vague ideas as to its magnetic state.

Ewing made a series of experiments on iron in the following manner. Starting with iron as nearly destitute of magnetism as possible, he applied to it a magnetizing force, gradually increasing it by short steps up to a certain point, and noting the amount of the induction at each step. Then the magnetizing force was as gradually reduced to zero, when the iron was found to have retained most of the magnetism that it had when the force was highest. He then applied the magnetizing force in the reverse direction, gradually increasing it until it had reached a negative maximum as high as the former positive maximum, when it was found that the magnetism, having rapidly fallen to zero, had then increased in a negative direction and had attained a negative maximum almost exactly equal to the former positive maximum. The negative magnetizing force was again gradually reduced, and when it had reached zero, the iron was again found to have retained most of its magnetism. A positive magnetizing force was again applied and gradually increased up to its former value, when the magnetism reached the same value as before. Figure 2 gives an example of the kind of curve that was obtained as a result of these experiments, and closely resembles his hysteresis curves for cast iron. Figure 3 also shows two of Ewing's curves, both taken with one sample of very soft wrought iron, the maximum magnetization being very much greater in the larger one than in the smaller. The arrows indicate the order in which the observations were taken.

I shall not attempt to mention all the interesting points that might be brought out by a study of these curves, but shall confine myself to one salient fact, which is there clearly shown, namely, that it requires an expenditure of energy to magnetize and demagnetize iron.

The amount of energy required for one complete reversal of the magnetism in iron (that is, from a positive to a negative maximum, and back again) is proportional to the area included in the curve of hysteresis. This is susceptible of a simple proof by calculus, but I will not take up space by giving it here. This behavior of the iron

is broadly the phenomenon to which Ewing has given the name hysteresis, and it is to this phenomenon that those electrical men, who are concerned with alternating currents, are giving the largest share of their attention.

This hysteretic loss of energy must be present wherever the magnetism of iron is increased or decreased. It is even present when the magnetism is only changed in direction and not reversed,

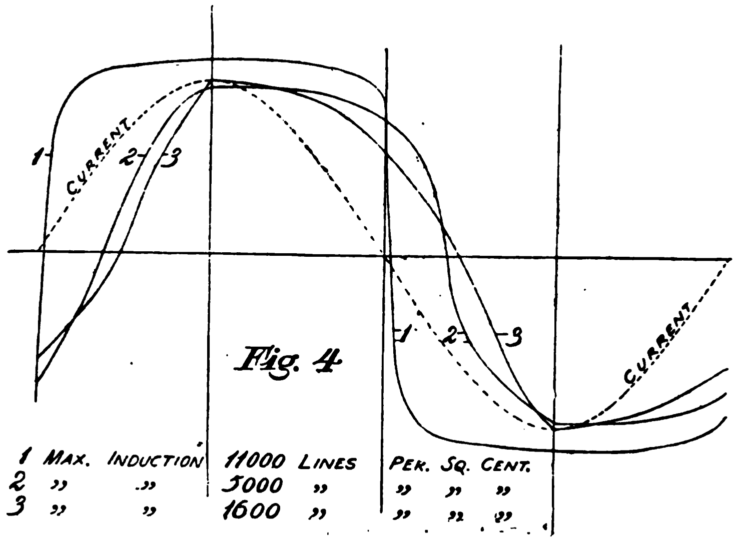


Fig. 4

as, for instance, in the revolving armature of a dynamo or motor. It is better studied in alternating current apparatus, however, of which the alternating current transformer will furnish the best example of its effect.

Until very recently the analysis of the reactions in transformers proceeded on the assumption that all the quantities involved varied according to the sine law. The primary E. M. F. and current, the secondary E. M. F. and current, and the magnetism, were all supposed to be simple sine curves. When Ewing's researches were made public, it was immediately seen that, if the current followed the sine law, the magnetism could not do so, and the electricians proceeded to plot the shape of the magnetism curves, assuming the

curve of current to be a sine curve, and using the data given by Ewing.

I plotted out several of these curves for different degrees of saturation, and give them in Fig. 4. There the dotted curve is the current curve plotted as a sine curve. The other three curves show the form of the resulting magnetization curves: No. 1, for a maximum magnetization of 11,000 lines per square cent.; No. 2, for 5,000 lines per square cent., and No. 3, for 1,600 lines per square cent. They are copies of some I have, which were all drawn to different scales, but the shape of the curves is well enough shown. The shape of these curves, which, irregular as they are, have been somewhat smoothed out in the copying, was enough to appal the mathematician, and I am not aware that any effort was made to analyse them.

The theory of transformers remained in this shape then till December, 1889, when Professor Ryan, of Cornell University, read a paper before the American Institute of Electrical Engineers on "Transformers." He showed conclusively in this paper as a result of experiment that, instead of the *currents* following the sine law, it was the *magnetism* that followed the sine law, while the current curve was of such a shape as would produce such a curve of magnetism, assuming Ewing's results to hold good in transformers. Figure 5 shows the form of the primary current and magnetism curves in a transformer with the secondary circuit open, taken from Ryan's paper.

Ryan also noticed another curious phenomenon, which can be explained by means of Fig. 6, (taken from his paper). In this figure the inner curve is a curve of hysteresis, taken by Ewing's method from the transformer that was under experiment. The outer curve represents the actual value of the magnetism that was found to be in the transformer when the iron was undergoing reversals of magnetism at the rate of about 140 a second. Ryan, I understand, attributes this increased loss of energy to a time lag in the magnetism. Ewing could not find that any time was required for the

iron to assume a permanent state of magnetism corresponding to a particular magnetizing force, but the changes of magnetism produced by his method were extremely slow as compared with the rapidity of the changes going on in a transformer. An English electrician, Mr. Evershed, is at present contributing a series of articles to the London *Electrician*, in which he attributes the same phenomenon to the Foucault currents in the iron. Which is right, or whether either is right will have to remain in doubt till more

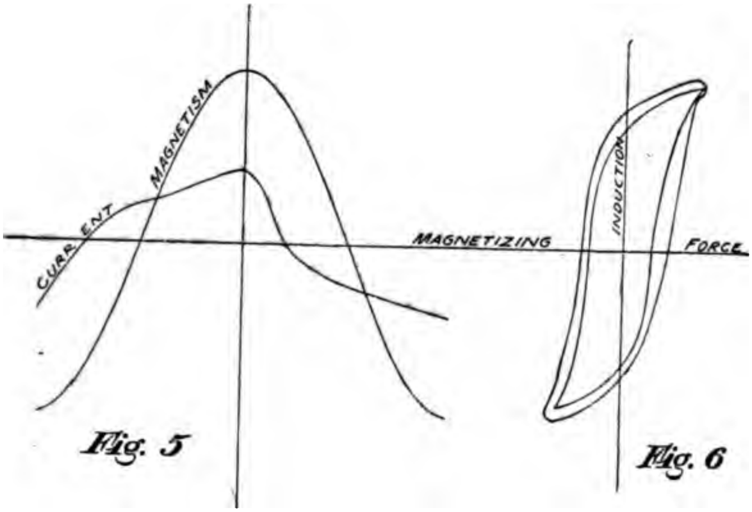


Fig. 5 *Fig. 6*

light is thrown on the matter by further experiments. I am rather inclined to think that Professor Ryan is nearer the truth than Mr. Evershed, since his idea is more in accordance with the present theories of magnetism, though both causes may be present in producing the effect noted. This subject is a very interesting one and might be gone into much more thoroughly, but I pass on to a more important point, merely adding that we know almost nothing as to Foucault currents in laminated iron.

Ewing in his paper formulated a number of hypotheses to account for this behavior of the iron, chief among which was a static friction among the particles of the iron resisting their motion.

He conceived that the iron in its unmagnetized state consisted of a number of molecular magnets with their poles pointing in all directions, that when a magnetizing force was applied gradually, these molecular magnets were pulled around in the direction of the force, a few at a time, and that *the friction between them resisted their motion.* He has since then materially changed his ideas, and has presented a set of hypotheses which differ materially from these. Unfortunately for the electrical profession the paper in which he promulgated these ideas was read before the Royal Society, which does not publish its papers until some years after they are read. The electrical journals, however, have obtained a meagre abstract, from which we may get some idea of Ewing's experiments and their results.

He arranged a number of small, thin magnets on pivots, close together, but not touching each other, and designed to have the least possible friction, and then observed their behavior under different degrees of magnetizing force. This model was supposed to represent, on an enlarged scale, the actions taking place in the iron molecular magnets. As a result of experiments with this model, he formulated his hypotheses to account for the behavior of the iron when subjected to varying magnetizing forces. The most important of these hypotheses stated that there were points of equilibrium for the system at all degrees of magnetization, more or less stable, and that, therefore, more or less force was required to move the particles from these positions of equilibrium. The importance of this hypothesis will become clear when we remember that previously to this, only one point of equilibrium was supposed to exist, and that is when the iron is totally without magnetism. Examining Ewing's curves with the aid of this hypothesis, we might learn many interesting facts, but I will mention only one or two of them. We see, then, that the iron appears to be in a state of more stable equilibrium at high degrees of magnetization than at low. Then glancing at figures 1 and 2 we see that the curve rises from the state of no magnetization very gradually at first, from which we

may infer that the magnetic equilibrium is very stable at that point, but rapidly becomes very unstable.

In Ewing's first paper there is a very interesting and curious corroboration of his hypothesis, which is clearly shown in Fig. 7, This figure I have drawn roughly from memory. It will be observed there that he has stopped the gradual increase or decrease in the magnetizing force at several points on the curve, reversed its direction and returned to the original point, thus forming those very curious looking loops in the curve. The loop marked *A* is to be specially noted. At that point it will be seen that, although the

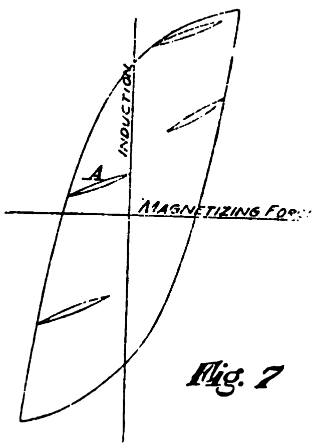


Fig. 7

magnetizing force is negative, the magnetism is still positive. Then as the magnetizing force is *decreased* to form the loop, the magnetism *increases*. The magnetizing force was at that point actually engaged in pulling the magnetism down, not against friction, for then there would be no tendency for the magnetism to go up when the force was withdrawn, but against a real force in the iron itself tending to increase its own magnetism. There is but one loop in Ewing's paper that shows this effect thus clearly, and I am not aware that it has been noticed before as a confirmation of Ewing's hypothesis.

I will not attempt, within the limits of this article, to show how this hypothesis will account for most of the known facts of hysteresis, as that subject is a large enough one to require a whole article for itself, but will content myself with propounding one query, which I have not been able to answer satisfactorily, and that is how, under this hypothesis, does the energy lost in hysteresis become transformed into heat, as it appears to be in transformers and other alternating current apparatus? The old theory, which supposed hysteresis to be frictional in its character, easily enough accounted for this, but at present I confess I do not see how the new hypothesis will.

So much for the behavior of iron and other metals under magnetic stress. Another interesting development has been made in regard to the lines of force of an electric current in air. We have generally thought of the electric current as having two distinct sets of properties, the one called electric, the other magnetic, the one taking place inside the conducting body, the other in the space around it. Maxwell's electro-magnetic theory of light, which was experimentally developed a few years ago by Hertz in his brilliant series of researches on electro-magnetic radiations has served to materially modify our ideas as to the intrinsic nature of the electric current. The subject has not yet been thoroughly worked out, but the tendency now is towards the idea that there is no radical difference between the properties of the current inside and outside of the conductor. Some have even supposed that the whole energy of the current lay in its magnetic properties. It is certainly well known that there are lines of force inside the conductor as well as outside, and whether there is anything else there it would be hard to say at the present stage of the matter.

This, then, is the status of the theory of magnetism up to date, and these tremendous strides have been largely the work of one man, Prof. J. A. Ewing, to whom all honor is therefore due for his splendid contributions to the science of magnetism.

METHOD OF FINDING THE DATE OF EASTER.

BY PROF. H. A. WOOD, OF THE STEVENS SCHOOL.

THE following is a simple method of ascertaining the date of Easter, or the Sunday on which it occurs. The tables extend from the year 1700 to 2100, a period of 400 years.

Several methods have been devised for finding the date of Easter for any year, but they are for the most part too complicated to be easily understood by the general public. By carefully studying the following tables and explanations the required date for any year can be readily found. Several examples are added to familiarize the learner with the use of the tables.

By the reformation of the Calendar, the 14th day of the paschal moon was brought back to the time of the Council of Nice, from which it had come to deviate more than four days. That council decreed that Easter Sunday should be celebrated on the *first Sunday* after the full moon, which happens upon or next after the 21st of March If a full moon falls upon a Sunday, Easter is the following Sunday. It is obvious from this that Easter cannot happen sooner than the 22d of March, nor later than the 25th of April, which have been called the paschal limits.

By the method of finding the date of Easter, as here explained- it is necessary to ascertain the Golden Number for the year, the Dominical Letter, and the Epact. As the Epacts are readily tabulated in connection with the Golden Numbers, we shall first give the table in which the Golden Number can be found for the required year. In the table following the Epact is found beneath the Golden Number for the year, the Index letters and Centennial years being given at the left.

The Golden Number, or Lunar Cycle, is a period of 19 years, when the sun and moon return very nearly to the same positions. It is sometimes called from the inventor, Meton, an Athenian astron-

omer, the Metonic Cycle. The Athenians had it inscribed in the public square in golden letters, whence the name. The number of the year in the cycle is called the Golden Number.

The Epact is a term employed to represent the age of the moon at the beginning of the year—that is, the number of days that have elapsed since the last new moon of the previous year. It enables the age of the moon to be readily computed for any day of the year.

The Romans represented the days of the week by the first seven letters of the alphabet, beginning each year with A, and repeating these letters throughout the year. The letter that falls on Sunday is now the only one used, and is called the Dominical Letter. The Solar Cycle is a period of 28 years when the same days of the week recur on the same days of the year.

Table of the Golden Numbers.

For any year from 1700 to 2100.

Look for the Golden Number under the Centennial opposite the Intermediate Year.						Centennial Years.			
						1800	1900	2000	1700
Intermediate Years.						Golden Numbers.			
XX	XX	XX	XX	XX	XX	15	1	6	10
1	20	39	58	77	96	16	2	7	11
2	21	40	59	78	97	17	3	8	12
3	22	41	60	79	98	18	4	9	13
4	23	42	61	80	99	19	5	10	14
5	24	43	62	81		1	6	11	15
6	25	44	63	82		2	7	12	16
7	26	45	64	83		3	8	13	17
8	27	46	65	84		4	9	14	18
9	28	47	66	85		5	10	15	19
10	29	48	67	86		6	11	16	1
11	30	49	68	87		7	12	17	2
12	31	50	69	88		8	13	18	3
13	32	51	70	89		9	14	19	4
14	33	52	71	90		10	15	1	5
15	34	53	72	91		11	16	2	6
16	35	54	73	92		12	17	3	7
17	36	55	74	93		13	18	4	8
18	37	56	75	94		14	19	5	9
19	38	57	76	95		15	1	6	10

Table for Finding the Dominical Letters.

Look for the Dominical Letter under the Centennial opposite the Intermediate Year.				The Centennial Years, Beginning with the Year 1700. Dominical Letters. 1800	1900	2000	1700
0	xx	xx	xx	E	G	B A	C
1	29	57	85	D	F	G	B
2	30	58	86	C	E	F	A
3	31	59	87	B	D	E	G
4	32	60	88	*A G	C B	D C	F E
5	33	61	89	F	A	B	D
6	34	62	90	E	G	A	C
7	35	63	91	D	F	G	B
8	36	64	92	C B	E D	F E	A G
9	37	65	93	A	C	D	F
10	38	66	94	G	B	C	E
11	39	67	95	F	A	B	D
12	40	68	96	E D	G F	A G	C B
13	41	69	97	C	E	F	A
14	42	70	98	B	D	E	G
15	43	71	99	A	C	D	F
16	44	72	x	G F	B A	C B	E D
17	45	73	x	E	G	A	C
18	46	74	x	D	F	G	B
19	47	75		C	E	F	A
20	48	76		B A	D C	E D	G F
21	49	77		G	B	C	E
22	50	78		F	A	B	D
23	51	79		E	G	A	C
24	52	80		D C	F E	G F	B A
25	53	81		B	D	E	G
26	54	82		A	C	D	F
27	55	83		G	B	C	E
28	56	84		F E	A G	B A	D C

*** When two letters appear, the first is used for January and February, the second for the remaining months of the year.**

Table of the Epacts.

Golden Numbers.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Epacts for the Years Corresponding to the Golden Numbers.																				
A................	1700, 1800	0	11	22	3	14	25	6	17	28	9	20	1	12	23	4	15	26	7	18
B......	1900, 2000	29	10	21	2	13	24	5	16	27	8	19	0	11	22	3	14	25	6	17

Table for Finding Easter.

Dominical Letters.	Epacts							Date of Easter.
	23	22	21	20	19	..	..	March 26.
	18	17	16	15	14	13	12	April 2.
A...........	11	10	9	8	7	6	5	" 9.
	4	3	2	1	0	29	28	" 16.
	27	26	25	24	..	..	..	" 23.
	23	22	21	20	19	18	..	March 27.
	17	16	15	14	13	12	11	April 3.
B...........	10	9	8	7	6	5	4	" 10.
	3	2	1	0	29	28	27	" 17.
	26	25	24	..	..	..	..	" 24.
	23	22	21	20	19	18	17	March 28.
	16	15	14	13	12	11	10	April 4.
C...........	9	8	7	6	5	4	3	" 11.
	2	1	0	29	28	27	26	" 18.
	25	24	..	..	..	..	..	" 25.
	23	..	..	..	..	..	..	March 22.
	22	21	20	19	18	17	16	" 29.
D...........	15	14	13	12	11	10	9	April 5.
	8	7	6	5	4	3	2	" 12.
	1 & 0	29	28	27	26	25	24	" 19.
	23	22	..	..	..	..	..	March 23.
	21	20	19	18	17	16	15	" 30.
E...........	14	13	12	11	10	9	8	April 6.
	7	6	5	4	3	2	1	" 13.
	0	29	28	27	26	25	24	" 20.
	23	22	21	..	..	..	..	March 24.
	20	19	18	17	16	15	14	" 31.
F...........	13	12	11	10	9	8	7	April 7.
	6	5	4	3	2	1	0	" 14.
	29	28	27	26	25	24	..	" 21.
	23	22	21	20	..	..	..	March 25.
	19	18	17	16	15	14	13	April 1.
G...........	12	11	10	9	8	7	6	" 8.
	5	4	3	2	1	0	29	" 15.
	28	27	26	25	24	..	..	" 22.

The Table of Epacts is so arranged that beneath the Golden Number is given the Epact corresponding to the G. N. for the required year. It will be observed that the same Index Letter, A, answers for 200 years, beginning with the centennial year 1700; and that B, in like manner, answers for the following 200 years, beginning with 1900. For finding Easter we then have the following

RULE.

1. Find the Golden Number for the required year.

2. In the "Table of the Epacts" find the Epact for the year corresponding to the Golden Number.

3. Find the Dominical Letter for the year.

4. In the "Table for Finding Easter," opposite the Dominical Letter and Epact for the year, will be found the date of Easter.

EXAMPLES.

1. Required, the date of Easter for 1891. Reference to the tables gives the Golden Number to be 11; from which we find the corresponding Epact to be 9. The D. L. is D. Under "Table for Finding Easter," opposite D and Epact 20, is March 29, date of Easter.

2. Find the date of Easter, 100 years hence, or for 1991. The G. N. is 16; Epact 3; D. L., F. Easter will occur March 31.

3. Show that Easter fell on April 17, in 1870; on April 25, in 1886, and that it will come on April 15, 1900.

MEETING OF THE ALUMNI ASSOCIATION.

THE winter meeting of the Alumni Association was held in the hall of the Stevens School on Tuesday evening, January 20, 1891.

The alumni, members of the Faculty, and invited guests present numbered about 75. The latter included Messrs. Horace See, Oberlin Smith, and George H. Babcock, Past-Presidents of the American Society of Mechanical Engineers; Mr. William N. Forney, Editor of the *Railroad and Engineering Journal*, Mr. William N. Wiley, Treasurer of the American Society of Mechanical Engineers; Col. E. A. Stevens, and Mr. C. J. H. Woodbury, of Boston.

Mr. William Kent, the presiding officer, stated that he presumed he had been called to the chair in view of his holding the

office of Alumni Trustee, and would avail himself of this opportunity to thank the members of the association for the honor they conferred upon him as their representative in the Board of Trustees.

He also said that for the first time since the organization of the Alumni Association the meeting was favored with the presence of invited guests who were not connected with the Institute, and expressed the hope that this precedent now inaugurated would be continued.

Before the topic to be presented for discussion was announced the routine business of the meeting was first disposed of.

The Secretary announced that the Undergraduates had adopted a college pin, which could be furnished to alumni at a cost of $4.25.

The Managing Editor of the INDICATOR reported that by increasing the subscription price of the INDICATOR the magazine had been made self-sustaining, and that he believed there would be a small surplus at the end of the year. He asked the association to be relieved of some of the editorial work, as the existing arrangement demanded too much of his time. The matter was upon motion referred to the Executive Committee with power.

The Chair announced that there would be a meeting of the class of '88 immediately after adjournment.

The Corresponding Secretary reported having received a number of replies from gentlemen who had been invited to be present, and who expressed their regrets for being unable to attend.

This disposed of the business part of the meeting, and the Chair then stated that the Executive Committee had selected as a topic for discussion the following: "Should the Institute's course be changed from a four year to a five year course," and said that the topic suggested the broader one. "How may the course of instruction in our technical schools be improved?"

In the course of his remarks, Mr. Kent referred to the difficulty experienced by the early graduates of the Institute to secure

satisfactory positions—citing one graduate, who accepted a position in a railroad machine shop at 50 cents a day, and another who entered a car shop at 90 cents a day; he also spoke of the rapid advancement of these men to responsible and lucrative positions, and mentioned the fact that many of the earlier graduates were now engaging the younger ones as their assistants, and that members of the graduating class now often have positions assured them before graduation.

He expressed the view that, to meet the demand for better educated men, technical schools must either continue to do as Stevens has been doing, gradually raise the standard of admission, and thus require more work to be done in the preparatory schools, or they must establish a five-year course. The course adopted by Stevens has advanced the work in several of its departments to such an extent that a further development demands a better equipment in her laboratories; a new chemical and metallurgical laboratory should be added immediately.

And then he said the main question arises: "How is all this to be done? Where is the money to come from? Where is the Fayerweather or the Fogg who will increase the endowment of the college? This leads me to the sad confession that Stevens is poor But this is no disgrace as (quoting a Harvard professor) 'no college is filling the full measure of its usefulness unless it is poor. It must always spend all its income, and always have new scholarships, professorships, and fellowships to be endowed whenever its income increases.'"

After the Chair had thus introduced the subject for discussion the meeting was favored with remarks from a number of the invited guests, from President Morton and Professors Wood and Denton, of the Faculty, and from several of the alumni.

Professor Denton opened the discussion favoring a five-year course, in order that more time might be devoted to the solution of engineering problems requiring the application of the theoretical knowledge acquired in the earlier part of the course. He thought the preparatory studies in mathematics and mechanics occupied so

large a part of the course that not sufficient time remained for practical exercises designed to make the student self-reliant, and to inspire him with the necessary confidence when he begins to practice his profession.

Messrs. Horace See, G. H. Babcock and C. J. H. Woodbury, spoke briefly, saying that they were not familiar with the Institute's course, and regretted, therefore, not to be able to enter more fully in the discussion of the question.

Mr. Alex. C. Humphreys, '81, made a few remarks upon the question, but has kindly complied with our request, and has since prepared a more extended exposition of his views, which we give herewith :

" Great interest is now being displayed, and perhaps especially in this country, in college and university methods, and the discussions on the questions involved are being participated in by many of our ablest and best-known educators; the great variance in the opinions held by these representative men goes to show the magnitude of the subject, and the necessity for treating all the questions involved in the broadest possible spirit.

The proposal to continue at this time, in a more formal way, through the columns of the INDICATOR, the informal discussion of the Stevens five years question, commenced at the last midwinter meeting of the Alumni Association seems, therefore, to be particularly opportune.

It is well, also, that this continuance of the discussion should be participated in, as was the informal opening referred to, by professional educators, engineers and men of affairs outside of Stevens, and by Stevens Alumni.

Those of us that belong to the last class know what kindly and thoughtful consideration all suggestions will receive from the Trustees, the President and the Faculty.

It is well to remember, that Stevens, by her four years course, attempts to fill, not only the place occupied by the University special course, but also attempts, at least in part, to do the same for the college baccalaureate course.

In this Stevens has not differed, perhaps, from other technical colleges, except as to detail and standard. This difficulty of crowding into a four year course, the work of general education or

culture, and the special education, is met with also in connection with the other professions, and especially that of Law and Medicine. And are not these professions also aroused to the necessity for improvement?

This crowding of the course may lead in part or in whole to three things:

1. Neglect of the general educational studies.
2. Neglect of the special (engineering) studies.
3. Overwork of the student.

From my own experience as a student, and my later experience, especially as the employer of Stevens and other graduates, I firmly believe that those who have shaped the course of Stevens (and is it unfair to specially refer to President Morton?) have successfully followed a most admirable compromise course. The Stevens student is called upon to devote considerable time and earnest work to general educational studies. He is put through a course in engineering which shows that there has been held firmly in mind Rankine's admonition in regard to harmony of theory and practice; and in order to graduate he must work intelligently and conscientiously, husbanding his time, as he will be obliged to do after he gets away from his instructors, if he expects to rise in his chosen profession.

As far as I have had the opportunity of judging, I have found, as a rule, the Stevens graduates to compare favorably with the graduates of other colleges and technical schools of the United States, and with engineers educated in foreign lands. Especially have I found them capable of taking hold of *new* work, requiring original investigation and special study.

But advances are being made. Shall Stevens lag? She can certainly claim that, so far, no institute of learning leads her in the special course of Mechanical Engineering. Confining herself to this single course (and I hope she always will), she enjoys an immense advantage—the advantage of concentration of effort. If, then, she decides to devote herself in the future, as she has in the past, exclusively to the special education of mechanical engineers, let us see to it that she is always in the lead, turning out not only able engineers, but also educated gentlemen.

I believe it is not denied that material progress in the elevation and strengthening of the course has been made during the last ten years; the shop course has been systematized and enlarged, theo-

retical studies have been added and further opportunity for practice has been given. And the time for these additions has been found by raising the standard for entrance and using the time of the course to better advantage.

But the demand is made for further extension of the course. If so extended, on what lines shall it be extended, and how shall the time be found?

Many seem to be of the opinion that greater attention and more time should be given to shop work.

Others think that more time should be given to special study and investigation in some of the more prominent subdivisions of engineering, such as electrical engineering, iron-working, ventilation, etc.

Others think that more attention should be given to the subjects coming under the head of general education and culture, and also to the study of the ethics of our profession.

Others, again, think that further time and attention should be given to the application of the information obtained in the text-books and the class and lecture rooms.

If I am correctly informed as to the curriculum now followed at Stevens, I do not believe that there is much necessity for enlargement on the first two points.

In shop practice it does not seem necessary that the mechanical engineer should be able to use all kinds of tools with the dexterity and facility of an expert mechanic. He should have such general knowledge and dexterity as to the handling of tools as will enable him to determine how a piece of work can be executed so as to give the maximum of efficiency at a minimum of expense. Later, if he settles down in some particular line, he *may* find it an advantage to acquire complete dexterity and facility in the handling of such tools as he is most concerned in in his special line of work.

But, ordinarily, the mechanical engineer does not need such a measure of dexterity and facility in handling tools as would fit him to compete with the mechanic, who has to actually depend upon those acquirements for the earning of his daily wages.

I do not believe Stevens is in need of any great improvement in this direction, and this part of the question will be met with in the further systematizing of, and small additions to, the course which will naturally come with further experience, provided the funds are available.

In regard to an enlargement in the direction of special subdivisions of the special study of mechanical engineering, I believe that no decided move should be made in this direction, except after the most careful and deliberate consideration. Probably small improvements and additions will, from time to time, be found desirable. But, first and last, it should be borne in mind that the Stevens graduate should be a mechanical engineer. It is not to be lost sight of that special studies are narrowing, and that even in starting to follow the special study of mechanical engineering we must guard against such narrowing influence. For, although a special student, the mechanical engineer is not necessarily a specialist, as that word is now understood. After becoming a mechanical engineer he may elect to become a specialist, feeling that he has special ability or special opportunities in some one line; but first let him be the mechanical engineer. The great oculist does not become such until he has first become the well equipped doctor of medicine. Special lines of engineering should only be approached through general engineering studies, and general engineering studies should only be approached through a general educational course, if the graduate is to be a broad-minded man, instead of a narrow-minded specialist.

It would seem, therefore, that these special studies, for the benefit of would-be specialists, should be pursued outside of the Institute, or as a post-graduate course. Otherwise an injustice must be worked against the majority.

Now we come to the third point—namely, the giving of more attention to general culture, and also to the study of the ethics of our profession.

I fear if the students are of the same mind generally that they were ten years ago, they will protest against any extension on these lines. I remember that many expressed surprise and disgust at what they termed the stupidity of the Faculty in insisting upon certain studies being pursued which seemed to them to be in no way necessary for the proper training of the mechanical engineer.

Every year I am more and more convinced that Stevens does not devote too much attention to these subjects, but that it would be well, if possible, to give them further attention and time. On the score of utility alone, and apart from the *educational* value of these studies, the student can well afford to devote further time and effort to the acquiring of a better style and greater facility in the

use of the English language. He will find, as he gets out in the world to practice his profession, no matter how capable he may be of handling the problems he comes in contact with, he needs also to be able to give logical and forcible expression to his views and opinions.

It would also be well if the Institute course gave the student the opportunity for practice in correctly expressing his thoughts while on his feet facing an audience. How much many of us regret that we did not have sufficient of this practice.

In some quarters there seems to be an idea that Americans do not need practice in public speaking. Such an idea, I think, is entirely erroneous. Is it not the fact that the *practice* in debate, afforded to many Americans by membership in lodges, societies and municipal and other governing bodies, is what gives them this facility? But what practice does he have who goes from school to Stevens, and so out to the world, where he is to find himself constantly embarrassed for lack of this facility?

And sufficient time should be given to the consideration of professional ethics. The student should be instructed that, no matter what his life's work is to be, only by doing that work honestly and conscientiously will he in the long run secure satisfaction to himself; and also that, so far as the powers and opportunities given to him permit, he must secure therefrom the best obtainable result.

In the informal opening discussion referred to, special stress was laid upon the desirability of warning the student of the temptations he will meet, when engaged in practical work, from the efforts at bribery with which he will be assailed. This is a question of the man, not the student; but certainly it is not amiss to point out to the student the special pitfalls which we *know* he will meet if he should be successful in gaining a reputation as an engineer. Forewarned may be forearmed in this case, for the attack is often made most insidiously.

Now we come to the question of the extension of the course, with the view of giving further attention to the application of the information obtained in the text books and the class and lecture rooms. I cannot do better than invite those interested in this subject to read, or reread, as the case may be, Rankine's Dissertation, delivered as an inaugural in 1855, before the Senate of the University of Glasgow, and printed as a preliminary introduction to his Applied Mechanics.

In it he says: "Mechanical knowledge may obviously be distinguished into three kinds—purely scientific knowledge, purely practical knowledge, and that intermediate knowledge which relates to the application of scientific principles to practical purposes, and which arises from understanding the harmony of theory and practice."

"The mechanical engineer should have that scientifically practical skill which produces the greatest effect with the least possible expenditure of material and work."

It would seem to be well if the entire senior year could be devoted to the putting in practice of the scientific and practical knowledge so far acquired. And surely the way to do this is to free the student from the required class-room work and bring him into contact with the live engineering problems of the day, requiring him to work on these problems just as he will be called to work on them when he leaves the supporting arms of Stevens. Not in any way making this elective or light work, but expecting him to be able to do more real work this year than any previous year, as it is no more than fair to expect, in view of the strength he should have now gained. The degree only to be granted upon a thoroughly satisfactory showing during this last year of the student's ability to cope with the problems submitted. In accordance with Professor Denton's suggestion this work could well take the place of the present thesis work.

Now comes the question, if these changes are to be made, how shall the time be found for the work? And this at once suggests another question. Can more work be safely crowded into the four years' course?

Experience seems to show that, while the course is, as it should be, an unusually severe one, the large majority of those that have any right to expect to graduate are able to perform the work required. There may be a few exceptions, but the majority must not suffer for the exceptions; the exceptional cases can be specially cared for by spreading the course over more than the prescribed time, as could, no doubt, be done without any objection on the part of the Faculty in worthy cases, and as is regularly done at the Massachusetts Institute, by allowing the students the option of a five years' course without loss of standing.

But there seems to be no chance for any great gain of time here, though it is held by some that, by readjustment, a little more

work could safely be performed in the first and fourth years. A material gain, one full term, can be made by abandoning the writing of a thesis, as before referred to.

But to carry out the suggested additions probably two terms more are yet required. And, therefore, we come back to the original question: How shall the time be found for this additional work? The answer at once suggested as the easiest solution is add a fifth year. But is this necessary, and is it wise?

I believe it is neither necessary nor wise.

President Morton has pointed out that Stevens has been steadily raising its standard of admission, and has so gained time.

These changes suggested must be made step by step. They will naturally be so made. As it is found possible then, let the entrance requirements be advanced, and the course be added to.

Stevens and like institutes are in better position to make this change than are the ordinary colleges. For it must be recognized that the Technical Institute should supply in a great measure what is supplied by a higher university course, something beyond the baccalaureate course.

If the system suggested by one university president should gain favor, it would help to solve this question—namely, that certain universities, affording the best facilities for advanced courses, "should receive without examination students who had completed the sophomore year in any reputable college." The students would then take up their university course at the beginning of the junior year. And having completed those two years they would receive their B. A. degrees. Two years more of the university course would then have to be completed to obtain the professional or advanced degree.

If any such system should be developed, Stevens might well expect to get her share of the college men, who, after two years of general work, had elected to take up her special line of study.

In these discussions referred to, one point seems to be generally conceded—namely, that the *preparatory* schools of our country are not as a rule what they should be, and do not compare favorably with those of some other countries, and that, therefore, the colleges are handicapped by being obliged, during the four years' college course, to make good the deficiencies of many of these schools.

Stevens suffers with the others. But this evil will undoubtedly be gradually curtailed, and so all the colleges and universities will

gain time. Stevens has also this matter, in part, in her own hand, through her preparatory school, which will, no doubt, receive more and more of the students intending to enter the Institute, even if it is only for a last year, for the purpose of rounding off, preparatory to commencing the regular course. But still there must be many that cannot enjoy this advantage. Cannot these, at least in part, be prepared for the higher entrance requirements by well-organized methods for giving definite information and guidance by mail as to the lines which must be followed to fit the student for entrance?

We know of much good work which has been done by means of lesson papers passed through the mail. Such a system, in a modified degree, could be well made available, and at no great expense, to assist the worthy and ambitious but poor student to prepare himself, perhaps by night study only, for even these more severe entrance requirements.

I also think that these entrance requirements should call, not only for proficiency in mathematical principles, but such facility in handling the mathematical problems included in the requirements as to relieve the student of all embarrassment, on this account, in connection with the problems in higher mathematics to be met in the four years' course. It is not lost sight of that while some men have, or acquire with comparative ease, this facility, others may acquire proficiency without acquiring any great facility, and that too severe a requirement in this direction for entrance might work severely with some. I believe that almost without exception the student experiencing this severity would be well repaid for the extra effort he had been obliged to put forth, by the after ease with which he could perform the incidental work in connection with the problems in the higher mathematics. While, as already said, special facility in the handling of tools does not seem to be necessary to the mechanical engineer as it is to the mechanic, too great facility in the handling of the ordinary mathematical problems cannot be acquired. Such facility in a life of engineering work means an immense total saving of wear and tear.

To carry out fully such an extension of the course as has been outlined would undoubtedly call for additional funds. Stevens Institute occupies rather an unfortunate position in this connection, for while endowed generously by Mr. Stevens, the endowment does not permit of any such extensions; and while this endowment has been reinforced several times by generous assistance given for

special objects, and especially by President Morton, no additional benefactions for application to general purposes have been received, and therefore the extensions, if decided upon, will have to be provided for by money to be specially secured. Perhaps it is unfortunate that the general public believes Stevens to be so endowed as to be in no need of this additional help. Many colleges and universities can look to their alumni for help in such cases. Unfortunately Stevens is young, and, therefore, her alumni are all comparatively young men; but not only that, their chosen profession does not, as a rule, afford opportunities for the rapid acquirement of wealth, and it is to be feared that the means for keeping Stevens Institute in the van as a leader of special education cannot be looked for from members of the alumni. While they can help, and should help to the very utmost of their ability, for no alumnus owes more to his alma mater than does the Stevens alumnus to his, still we must hope that some larger help will be furnished from the outside. And while it does not commend itself to us to go "fishing for millionaires," as was facetiously suggested at the informal discussion of the present subject, perhaps we may all be forgiven if we hope that a millionaire may come and deliberately put himself in the net, without being fished for."

Mr. Oberlin Smith followed Mr. Humphreys and discussed the question at some length; he said:

"Among my earliest engineering experiences, at the age of seven years, was the examination and manipulation of a wonderful rat-trap invented by an uncle of mine, who, by the way, was not an engineer. This trap enabled each rat, to the extent of a dozen or so, to hide himself away, and at the same time *reset* the trap for the next rat. Now it strikes me that the trap which my friend Mr. Babcock refers to, as having caught him here to-night, is very much like the one I have been describing, where everybody who gets on his feet sets a trap for the next fellow.

My eloquent forerunner, Professor Denton, has told us that he did not know anything at all when he came here to-night, and was enabled to make a decent speech only by "pumping" two or three of the students after he got in. Your present speaker, Mr. Chairman, is even worse off than this, for he came without knowing anything about the subject in hand, and, not having been able to do any student pumping, he doesn't know anything now.

The question before us to-night seems to be whether a four or five years course is best for a technical education. Now, when I ask my little girl whether she will have bread or toast, she answers, "pie!" Following the same line of thought my impulse, when asked to choose between four and five years, would be to say, "six." It seems to me that, within reasonable limits, the longer course any engineering student can take the better he is off. It is, after all, only a question of how much time and money he can afford to devote to thus grounding himself in preparation for his life work. As regards time, I think a student cannot afford to economize. He will do far more work in the long run by beginning actual professional life a year or two later, and putting this amount of time into additional studies, either theoretical or practical, or both. If it becomes a matter of money, the case is, of course, different with different individuals. If a young man can pecuniarily afford the longer course, well and good. If he cannot, and cannot earn sufficient as he goes along to keep himself going, then, of course, he must cut it short.

It is, however, often the case that a student can, after reducing his finances to a very low "voltage," commence to accumulate pressure again, upon the storage battery principle, by leaving school for a time and earning money in some active field of work, which, preferably, should be such as to increase his engineering experience in the special department in which he intends to practice. If a young man is physically able to stand it, he can put in a long summer vacation in gaining both experience and cash, instead of adjourning to a watering place or going fishing. I do not mean by this to deprecate the value of amusement and recreation, as each one should seek for as full a share of such restoratives as possible; but there are many cases where time devoted to the same can profitably be shortened.

Illustrating this: I know of a case where a brilliant young man, belonging to a family whose long line of professional instincts and traditions ran in quite other directions than mechanical work, left his studies at one of our leading universities, where he had been devoting himself especially to electricity, at the beginning of a long vacation, to become a motorneer (or whatever the proper name may be) upon a street car, and persevered in this work all summer—thereby much increasing his practical experience by the hard knocks which he was obliged to take. This policy was, the following summer, repeated by his becoming a temporary apprentice in a dynamo factory.

One reason why the present term at a school like this seems to me short is that there does not appear to be sufficient time, while following the regular curriculum, for practical work in shop and field. My experience as a manufacturer of machinery has taught me that an ordinary boy cannot become a good machinist without three or four years of solid shop work. This time can, of course, become very much shortened when he is especially trained in the best possible way, and taught the theory of his manipulations, as is the case in an institution like this. I think, however, that sufficient importance is not generally given to the idea that a mechanical engineer should be a good machinist.

In advocating a longer term, I would therefore lay particular stress upon using part of the additional time for gaining real experience of this kind, so as to be the better able in future years to conquer Dame Nature with her own weapons.

Suppose an engineer should give six years of his life to the study of his profession; it would not equal the seven years which is given to theology in college and seminary. Even so much as this does not in all cases make a man know too much, as doubtless we have some of us occasionally seen in the case of a graduated theologue who did not seem to possess as much knowledge as he started with. I should say, therefore, to every student: Claim from your alma mater all you *want;* and want all the learning you can get, *when* you can, and *how* you can. To every college I would say: Give such students *all they want.*"

President Morton then explained the plan that has been pursued by the Trustees of the Institute and gave his views upon the question under discussion. His remarks were in substance as follows:

"When the Stevens Institute of Technology was founded about twenty years ago, it came into the world under certain conditions of environment to which it was necessary that its structure and line of development should be adapted in order that it might survive and grow into its best capacity for usefulness.

This environment consisted, in the first place, in a certain standard in preparatory schools from which the Institute might draw a supply of students, and in institutions of learning which would be its compeers and units of comparison.

It was manifest at a glance that the course of the Institute must be so arranged as to allow of the admission of students prepared in mathematics and other branches only as far as the ordinary schools carried their pupils; and that we could not demand at the outset a higher standard for admission than the ordinary colleges required.

It was also supposed, though not so certainly apparent, that it would be a very difficult thing for a student starting with only such preparation as we have indicated, to acquire in four years all that was desirable for a Mechanical Engineer even at the very entrance of his professional life.

It was, however, evident that just as no supply of students could be obtained if a higher preparation was demanded for admission than that furnished by the schools, so all, or nearly all, attainable students would be discouraged and frightened away by the unparalleled prospect of a five years' course, where some technical schools were, in fact, offering a course of three years.

It was, therefore, decided to accept the existing standard of preparation and to do the best possible with a four years' course, but to raise the standard of admission as rapidly as was found possible, believing that the schools would follow if the advance was not too rapid.

This policy has been steadily pursued and its success has been largely secured by the aid of our own preparatory department, the Stevens School, which has grown with us and kept pace with our advance.

At the present time our requirements for admission to the Freshmen Class are fully equal to those for admission to the Sophomore Class of our early years.

In other words, we have already gained a year on this end of the course.

It is true that the development of engineering science has, in the meantime, added considerably to the material it is desirable for us to deal with during our four year course, and thus we still find our students crowded with desirable work which there is but scant time to go over; but I think that a continuation of the old policy is the best way out of this difficulty; and that imitating, as it does, the natural processes of gradual and not sudden growth and development will be safe to follow with the view of ultimately making our course a purely professional one, for which the general and higher

preparation will be furnished by schools which will grow up like our own Stevens School, to fill the demand created by the progress of Engineering Education.

As we cut off one subject after another from the beginning, by requiring it as a part of the requisite preparation, we shall generally add something to the other end to meet the new developments, and for this addition assistance will always be required; for, though we have been able to accomplish a remarkable amount of work with our original moderate endowment, supplemented by occasional small though timely assistance, we have not been able to do by any means all that was desirable, and can see, in the near future, many things which it would be most desirable to undertake if the means were available."

Mr. W. N. Forney called attention to the necessity of physical culture to maintain the body in a healthy condition when the mental faculties are being severely taxed.

He referred to the importance of a course in the ethics of engineering, which should put the engineer upon his guard against attempts at bribery, some of which are most covertly made.

He also called attention to the necessity of a thorough course in English, designed to give the student a training that will enable him to express his thoughts in precise language and in a logical manner.

Professor Wood and Mr. A. R. Wolff, '76, also made remarks upon the question.

The prevailing idea in the general discussion of the subject was that the length of the course in technical schools—whether it should be three, four, or five years, or longer—depended almost entirely upon the standard required for admission.

In reference to the Institute's course, it was shown that the additions to the requirements for entrance had lengthened the course about one year, the additional year being spent in the preparatory studies.

At the close of the interesting discussion the meeting adjourned to the adjoining rooms where a collation had been served, and a very pleasant hour was here spent in social chat, when the gathering finally dispersed.

The members present at the meeting were :

Jas. S. Alden, '84.
Leon Bandaret, '87.
Henry A. Beckmeyer, '76.
Henry A. Bang, '88.
John A. Bensel, '84.
Richd. Beyer, '88.
Geo. M. Bond, '80.
Wm. H. Bristol, '84.
Wm. N. Carlton, '90.
Wm. T. Clerk, '85.
Edwin J. Cook, '86.
J. H. Cuntz, '87.
Jas. E. Denton, '75.
Wm. S. Dilworth, '85.
Geo. Dinkle, Jr., '88.
Walter S. Dix, '87.
Paul Doty, '88.
Henry L. Ebsen, '89.
Wm. Ebsen, '90.
J. Hector Fezandiè, '75.
J. Day Flack, '87.
William Fox, '86.
Wm. E. Geyer, '77.
D. H. Gildersleeve, '89.
P. C. A. Graupner, '89.
Fredk. Gubelman, '89.
Sam'l D. Graydon, '75.
H. Addison Hickok, '83.
Wallace M. Hill, '89.
E. E. Hinkle, '90.
Wm. D. Hoxie, '89.
Alex. C. Humphreys, '81.
Frank E. Idell, '77.
F. E. Jackson, '86.
D. S. Jacobus, '84.
E. H. Kiernan, '87.
W. F. Lawrence, '90.
Prof. Leeds.
Wm. L. Lyall, '84.
Prof. MacCord.
Prof. Mayer.
Jno. A. McCulloch, '86.
Jos. A. McElroy, '87.
Embury McLean, '88.
Prof. Morton.
Lewis H. Nash, '77.
Robt. C. Oliphant, '89.
Washington E. Parsons, '87.
H. E. Peabody, '90.
P. E. Raquè, '76.
A. Riesenberger, '76.
E. M. Rosenberg, '89.
John M. Rusby, '85.
A. H. Schlesinger, '87.
Edw'd D. Self, '86.
Arthur L. Shreve, '88.
Sam'l F. Smith, '90.
Albert Spies, '81.
Geo. L. Todd, '90.
Henry Torrance, Jr., '90.
Alfred P. Trautwein, '76.
Fritz Uhlenhaut, Jr., '88.
W. Harvie Wade, '85.
Prof. Webb.
Alfred R. Wolff, '76.
John Wolff, '88.
Prof. Wood.
Durand Woodman, '80.
Ernest N. Wright, '83.
Wm. B. Yereance, '88.
William Kent, '76.

The following are some of the replies made to the invitation to attend the meeting, extended by the Executive Committee:

F. E. IDELL, ESQ., Corresponding Secretary,
Alumni Association Stevens Institute Technology,
41 Dey Street, New York.

DEAR SIR: Your letter has been received. I have been engaged for the last five weeks in a lawsuit at Pottsville and I could not answer the invitation sooner as I did not know whether it would be finished in time to enable me to avail myself of your kind invitation.

I am sorry to say that there is no prospect of the suit being finished within three weeks, which will prevent me from accepting your invitation.

Yours truly,
E. B. COXE.

MONTCLAIR, N. J., January 15, 1891.

MY DEAR SIR: I received some time ago an invitation to attend the semi-annual reunion of your Alumni, I think on the 20th inst. Feeling poorly at the time I laid it away to be replied to later and have lost it, and with it the Secretary's address.

Not wishing to slight so complimentary an attention, I take the liberty of sending you this line to ask you kindly to communicate to the Secretary of the Alumni Association my thanks for their courtesy and my regret that the state of my health renders it impossible for me to be present, which otherwise I should love to do. I am happy to be able to add that I am now so nearly well that it will, I hope, not be necessary for me much longer to avoid excitement and going out evenings. I am, dear sir,

Very truly yours,
HENRY MORTON, Ph. D., President, etc. CHAS. T. PORTER.

MR. F. E. IDELL, Secretary,
Alumni Association, Stevens Institute.

DEAR SIR: The invitation to attend the semi-annual meeting of the Alumni Association, on January 20, has been received. Please accept my thanks for the same, and, if it is possible, I shall be very glad to be present.

Yours truly,
E. D. LEAVITT.

NEW YORK, January 3, 1891.

F. E. IDELL, ESQ., Corresponding Secretary,
41 Dey Street, New York.

MY DEAR SIR: I feel very much honored by the invitation of the Alumni Asssociation of the Stevens Institute to attend their semi-annual meeting on the 20th inst. I regret, however, that the state of my health makes it necessary for me to decline, for the present, all invitations to entertainments of a quasi public nature. Please say to your fellow-mem-

bers that nobody appreciates the good work done by the Stevens Institute more than I do, and that it is a constant source of gratification that I was fortunate enough to be one of those who directed the attention of the late Mr. Stevens to the necessity of the institution which he founded, and which will carry his name down to posterity in grateful remembrance of his magnificent benefaction. Yours truly,

ABRAM S. HEWETT.

NEW YORK, January 9th, 1891.

F. E. IDELL, Corresponding Secretary, 41 Dey Street.

DEAR SIR: Since writing you on the 5th, accepting your invitation to attend the semi-annual meeting of your Alumni Association, I find that the annual meeting of an association to which I belong takes place on the same evening, and, much to my regret, I have to say I will not now be able to attend on the evening named in your invitation. Thanking you for your kindness in the matter I am, yours truly,

J. F. HOLLOWAY.

NEW YORK, January 12th, 1891.

MR. F. E. IDELL, Corresponding Secretary,
Alumni Association, Stevens Institute of Technology,
41 Dey Street, New York City.

MY DEAR SIR: I regret extremely that I cannot accept your kind invitation to attend the semi-annual meeting of the Alumni Association of the Stevens Institute of Technology. I have some very dear friends among the officers of the Institute, as well as among its Alumni, and it would have given me a great deal of pleasure to meet them on this particular occasion. Very sincerely yours,

C. F. CHANDLER.

January 12th, 1891.

MR. F. E. IDELL, 41 Dey Street, New York.

MY DEAR SIR: Since accepting your invitation to attend the semi-annual meeting of the Stevens Alumni Association the development of my business has necessitated a hasty trip to the Pacific Coast. I am obliged to leave on the 18th inst.

Please express my regrets to the gentlemen of the Executive Committee. I should have enjoyed the occasion very much, and regret that I cannot delay my departure until after the 20th.

Yours very truly,

JAMES C. BAYLES.

HARTFORD, January 5, 1891.

F. E. IDELL, Corresponding Secretary,
41 Dey Street, New York.

DEAR SIR: Replying to your very kind and courteous invitation to attend the semi-annual meeting of the Alumni Association of Stevens In-

stitute of Technology, to be convened on the 20th inst., I regret that the first month in the year brings so many duties and obligations that I feel compelled to decline. It would give me great pleasure to meet with you, for "*Stevens*" is among the pioneers in technical instruction in this country, and the men it has graduated have done good work. Anticipating for you a most enjoyable reunion,

I remain, very truly yours,
J. M. ALLEN.

BOSTON, January 8, 1891.

MR. F. E. IDELL.

DEAR SIR: I very much regret that I shall not be able to attend the Alumni Association meeting on the 20th of this month, to which you have so kindly invited me.

Very truly yours,
C. H. PEABODY.

SYRACUSE, N. Y., January 8, 1891.

F. E. IDELL, Corresponding Secretary,
41 Dey Street, New York.

DEAR SIR: Your valued invitation to attend the semi-annual meeting of the Alumni Association on the 20th is at hand. While it is not at all probable that I can avail myself of the pleasure, I should greatly like to attend. My (to me very agreeable) acquaintance with the Alumni of the Stevens has grown, as it has with its Professors, to nearly equal that of Cornell, and I should like to meet them in a body.

Thanking you for the invitation,
I am, very truly,
JOHN E. SWEET.

NEW YORK, January 8, 1891.

F. E. IDELL, 41 Dey Street, New York.

DEAR SIR: I am much gratified by your invitation of January 6, to attend with the Stevens Alumni at their semi-annual Meeting on January 20. It falls on the day selected for a Council Meeting of the Mechanical Engineers, which may render my attendance impossible; but if I am free that evening, it will give me great pleasure to be present, and meet many friends whom I have formed in your influential association.

Thanking you,
I remain, very truly,
F. R. HUTTON, Secretary.

ATHLETICS.

The season of 1891 has opened with a boom for outdoor athletics. Ever since the snow disappeared the campus has been the resort of base-ball fiends and ambitious handlers of the lacrosse stick. Every afternoon the teams go down to the athletic grounds and indulge in hard and earnest practice under the direction of their captains and coaches. Best of all is the general interest shown by the spectators who go down to criticize and encourage. The men on the scrubs are also showing up well. This is especially noticeable in lacrosse; whereas, last year, the captain had to play his attack against his defense, it is now generally possible to pick out a full scrub ; '94 has taken up the game so vigorously that two-thirds of her team may be seen practicing any afternoon.

This hearty and general interest insures us a successful season with our rivals, and a close and exciting series of interclass games.

With affairs in this prosperous and gratifying condition it is with regret that we have to announce the failure of the trustees to secure a lease of the St. George's Cricket Grounds. Stevens proposition that the St. George's Cricket Club should pay half the rental and take the grounds three days in the week was not accepted, and, as the trustees refused to accede to the latter's terms, negotiations were broken off. The St. George Cricket Club then made a private lease of the grounds from the Hoboken Land and Improvement Co.

The Athletic Association then appointed a committee to meet the cricket club and make arrangements to sub-lease the grounds from them.

The result of the negotiations is this: The Institute and School will have the entire use of the grounds on Tuesday and Thursday, and on Saturday mornings, and the use of half the grounds on Monday, Wednesday and Friday. The rent will be $350 per year, the lease standing in President Morton's name. The use of half the grounds does not, however, give us the use of any of the tennis courts, although the St. George's Club reserves the use of some on Institute days. This is a matter of much regret, but the committee were unable to arrange better terms.

Not the least unpleasant feature of this complication is the fact that it kills all hopes of further improvements to the ground this year. No grand stand, no track, no better dressing rooms.

What a pity it is that in this strait the Institute has no good friend who will step forward, buy the ground, and present it to her.

Base-ball.—Stevens will have a stronger base-ball team this year than for some time. Schalk and Cummings will be the battery as in last year's team, and the other places will be filled nearly as follows: 1st base, Weeks; 2d base, Strong; 3d base, Fielder; s. s., Paulsen; c. f., Darby; l. f., Coyne; r. f., Hake or MacKenzie. The uniform chosen is a gray

blouse, with "Stevens" in red across the breast, gray trousers and red stockings. The team this year has the services of a competent coach, and the chances are bright for defeating some of our old rivals.

It is much to be regretted that we do not belong to any collegiate league. This of itself would be a great incentive to put a good team in the field, and would increase the interest taken in our success.

The management, however, has arranged an interesting series of games, as will be seen by the following schedule, and other games will soon be announced.

Base-ball Schedule.

April 11	Stevens *vs.*	Englewood Field Club	at	Englewood.
" 18	"	Calumet	"	Hoboken.
" 29	"	Rutgers	"	New Brunswick.
May 1	"	Cornell	"	Ithaca.
" 5	"	Fordham College	"	Fordham.
" 10	"	Flushing Athletic Club	"	Flushing.
" 18	"	Wesleyan	"	Hoboken.
" 21	"	Columbia	"	Hoboken.
" 30	"	Montclair Athletic Club	"	Montclair.
June 3	"	Rutgers	"	Hoboken.

Lacrosse.—Stevens will put a first rate lacrosse team in the field this spring. H. Cuntz, Smith, Martin, Griswold, W. Cuntz, MacCord, Knox, Post, Merritt, of last year's team, and many others are practicing daily, so that there will be no lack of good material to choose from. Captain Smith has also announced his intention of choosing the team from among those who show up best in the practice games, and this has greatly increased the rivalry of the various candidates; '94 has shown an especial interest in the game, and will doubtless have one or two men on the 'varsity.

The suits adopted consist of a gray jersey with "Stevens" in red across the breast, white duck running trousers and red cap.

Our chances this year will also be greatly increased by the assistance of a competent coach, who is expected to arrive soon from Montreal, and will remain about six weeks. Under his instruction the individual playing and team work will be developed to the highest point.

Below we give the schedules of the Intercollegiate and Metropolitan Leagues, to both of which Stevens belongs. Besides these, the manager has under consideration a series of practice games with neighboring teams.

LACROSSE SCHEDULE.

1. Intercollegiate League.

May 9......Stevens *vs.* Lehigh..........................at Hoboken.
May 16.....Johns Hopkins *vs.* Lehigh......................at Baltimore.
May 23.....Stevens *vs* Johns Hopkins ....at Baltimore.

2. Metropolitan League.

April 11	....College City of N. Y. *vs.* Corinthian A. C....	at New York.
April 18	....Jersey City A. C. *vs* Brooklyns..............	at Brooklyn.
April 25	....Stevens *vs.* Corinthian A. C................	at Staten Island.
May 1	.....College City of N. Y. *vs.* Brooklyn...........	at Brooklyn.
May 2	.....Stevens *vs.* New York A. C..................	at Brooklyn.
May 5	.....Stevens *vs.* College City of N. Y............	at Hoboken.
May 9	.....New York A. C. *vs.* Corinthian A. C........	at Brooklyn.
May 14	.... Stevens *vs.* Brooklyn........................	at Hoboken.
May 16	.....Jersey City A. C. *vs.* Corinthian A. C........	at Staten Island.
May 19	.....Stevens *vs.* Jersey City A. C................	at Hoboken.
May 20	.....New York A. C. *vs.* Brooklyn	at Brooklyn.
May 23	. ...College City of N. Y. *vs.* New York A. C....	at New York.
May 23	.....Brooklyn *vs.* Corinthian A. C................	at Brooklyn.
May 30	.....New York A. C. *vs.* Jersey City A. C........	at Brooklyn.

INSTITUTE NOTES.

The examinations of the second term were held during the week beginning March 16. The number of students deficient in scholarship was unusually large, no less than nine having been dropped from the several classes.

Beginning with the next college year conditioned students will be re-examined at specified times and the following regulations will be enforced:

Students will be allowed to attend all classes while making up their conditions.

At the beginning of the *first term* conditioned students will be examined on dates fixed by schedule in annual catalogue.

Those who then fail in three departments will be immediately assigned to the next lower class.

Students who fail in one or two departments will be required to take, at once, a tutor or tutors appointed or approved by the President.

These students will receive another re-examination not later than three weeks after the beginning of the term, according to a schedule to be placed on the bulletin board.

Those who are still deficient in one department may be placed in a lower class, or allowed to go on with their own, according to the discretion of the President and the Professor, in whose department they are conditioned.

At the beginning of the *second* and *third terms* the first re-examination will be held two weeks from the beginning of the term, and the second re-examination three weeks later, according to schedules to be placed on the bulletin board.

Students failing at these examinations will be subject to the same action as stated under first term.

No other re-examination than those specified above will be allowed.

Absence from an examination will be regarded as equivalent to a failure.

THE CATALOGUE FOR 1891-2 has just appeared, and is similar in form and typography to that of last year. The frontispiece in this year's issue is a rear view of the Institute Buildings, made from a negative prepared by Prof. Bristol.

Another change noted is the omission of the subjects of the graduating theses in the list of alumni.

Rules regulating the re-examination of conditioned students are published for the first time. These rules, which go into effect at the beginning of the next college year, are given above.

PROF. DENTON DELIVERED A LECTURE on "The Construction of the New Croton Aqueduct," before the Brooklyn Institute, at the Y. M. C. A. Building, Brooklyn, Tuesday, March 17, 1891.

The lecturer presented lantern views of a map showing the location of the new aqueduct's source of water supply, and the routes of the new and old aqueducts, including a profile of the 30 miles of rock excavation forming the new aqueduct, also a cross section of the proposed mammoth Quaker Bridge dam, originally thought to be necessary to afford the desired extra storage capacity, and of other noted dams. The general civil engineering features of the new aqueduct were explained, and then views given of the interior of one portion of the rock tunnel (of which the aqueduct mainly consisted), illustrating the character of the ground excavated and the methods of drilling, blasting and timbering employed. Views of the several varieties of rock drills and air compressors used in the work were given, and their respective characteristics and advantages discussed. Tables and diagrams of tunneling performance on the new aqueduct were exhibited, and comparisons drawn from them with respect to the record of the great Arlberg Tunnel, showing to what extent, and why, the greatest speed of tunneling on the new aqueduct was far less than that attained at this famous Swiss tunnel.

THE TABLE HERE GIVEN exhibits the steady growth of the Institute for the twenty years of its existence. The numbers in the table represent the attendance at the end of the first term of each year.

Year 1871............	20	Year 1881...	133
" 1872............	44	" 1882............	131
" 1873............	63	" 1883............	186
" 1874...........	90	" 1884............	169
" 1875............	89	" 1885............	186
" 1876............	84	" 1886......... ..	172
" 1877	87	" 1887............	186
" 1878............	84	" 1888............	195
" 1879...........	83	" 1889............	200
" 1880............	101	" 1890............	213

PROF. WOOD CONTRIBUTED an article on the "Effect of Machinery Upon Labor," to *The Mechanical News*, New York, March 15, 1891.

PROF. JACOBUS HAS BEEN ELECTED to membership in the Holland Society of New York City.

WE publish in this issue an abstract of the lecture on "Drawing Room Practice," which is one of the regular lectures of the series delivered every year by Dr. Sellers in the Course of Engineering Practice.

We are pleased to announce that Prof. Sellers has in preparation, for publication in the INDICATOR, abstracts of other lectures of this series, which will appear in subsequent issues, and which together will contain a large amount of valuable information bearing upon the best machine shop practice of to-day, besides important suggestions regarding many of the engineering problems which are solved by the engineer in the practice of his profession.

AT THE HEARING OF TESTIMONY, last February, in the suit of Jersey City and Newark against Passaic for a permanent injunction to prevent the latter city from further polluting the Passaic River, Prof. Leeds was the principal witness. Having made numerous analyses of the water of the Passaic River, Prof. Leeds was able to give valuable testimony.

THE COMMENCEMENT EXERCISES of the Class of '91 will be held at Jacobs Hoboken Theatre, Thursday evening, June 18.

The competitive declamation for Commencement honors resulted in the selection of Alexander Dow as Valedictorian and Paul Spencer as Salutatorian.

C. J. FIELD, '86, lectured to the Senior Class last term, on Central Electric Light Stations.

AT THE REGULAR MEETING of the American Chemical Society, held March 20, 1891, Professor Leeds read a paper upon the subject: "Are Chemists generally prepared to abandon Clark's Test for Estimation of Hardness in Waters?"

TWO STANDARD YARD BARS, a gift from Mr. Gus. C. Henning, '76, have been recently added to the Institute's equipment of measuring apparatus.

These bars were standardized by Professor Mayer, in 1884, and have been used by Mr. Henning to measure off base lines for bridge triangulation and were then taken to the respective shops for comparison of the standards there used in the fabrication of bridge members. By this means corrections were applied to field measurements in locating bearing plates on which the bridges were to rest.

THE *Scientific American Supplement* of April 4, 1891, contains the tenth article of the series on "Instruments for Drawing Curves," by Prof. MacCord. The Polar Harmonic is the name given to the curve described, and a mechanical device is shown for generating the curve.

THE PRESENT FRESHMAN CLASS will be the first to take up the subject of Descriptive Geometry in the third term of the year. It will thus be possible

to finish the subject in the Sophomore year, a result that will commend its earlier introduction in the course.

THE PHOTOGRAPHIC SOCIETY held its third annual exhibition of lantern slide views in the Hall of the Stevens School in the latter part of February. The attendance was large and the applause elicited by the exhibits of the various members of the society was evidence that the result of their work was appreciated and enjoyed. The slides exhibited were made from photographs by Professor Bristol and Messrs. H. S. L. Verley and J. V. MacDonald.

The colored slides, representing western mountain scenery, which Professor Bristol had prepared for the occasion, were specially noteworthy.

'93's CLASS DINNER.—The Sophomores assembled at Martinelli's, on Fifth Avenue, Monday evening, February 9, to partake of their annual banquet. The inclement weather did not prevent a goodly number from gathering at the board. There were forty members of the class present, a fair showing out of a class of sixty. The menus were very pretty, but the table decorations did not equal those of the first dinner of the class. David Hilliard, a former member of '93, rejoined his class on this occasion, and was heartily welcomed by his old classmates.

A MEETING OF THE STEVENS SOCIAL SOCIETY was held Monday afternoon, April 13. It was resolved to collect the deficiency due to the last dance by an assessment upon the members. Mr. H. Cuntz was elected Treasurer in place of Mr. Moffett. The next dance will be held Monday, April 20, in the hall of the High School building. Messrs. Pearce, Harrison and H. Cuntz are the Committee.

INSTITUTE PERSONALS.

'76.

ALFRED P. TRAUTWEIN was married to Miss Mary Hendrick at Carbondale, Pa., Thursday, January 29, 1891.

P. E. RAQUE is Vice-President and Engineer of the Atlas Iron Construction Co., engineers and contractors for structural ironwork, Room 152, *Times* Building, New York City. This company does a general engineering and contracting business in structural and architectural iron-work for fire-proof buildings, iron roofs, bridges, etc.; also prepares plans, erects and equips shops, factories and manufacturing establishments.

AN ARTICLE on "Aluminium—Facts and Fiction," by William Kent, appeared in the *American Machinist*, February 5, 1891.

A. W. STAHL, U. S. N., read a paper on "The Modern Theory of Ocean Waves" at the meeting of the Technical Society of the Pacific Coast, March 6, 1891.

'78.

H. W. HAZARD holds the following official positions:

President, Dunbar Furnace Co., office at 224 So. Fourth Street, Philadelphia, Pa. Works at Dunbar, Pa.

Vice-President Crane Iron Co. Works at Catasauqua, Edge Hill and Macungie, Pa.

President, Radford-Crane Iron Co. Works at Radford, Va.

FRANK C. JONES, General Superintendent of the New York Belting and Packing Co., New York City, is a director of the New York Belting and Packing Co. Limited, and a member of the Committee of Management in New York.

'80.

DURAND WOODMAN delivered a lecture on "Aluminium, The Metal of the Future," before the E. Orange High School Alumni Association, at the Ashland School, on January 23, 1891.

'81.

ALEX. C. HUMPHREYS started, last month, for a short vacation to the Bermudas to take a much-needed rest.

'83.

F. A. MAGEE now represents the Engineering Equipment Company, Contractors for Steam and Electrical Equipment Materials, 73 Cortlandt Street, New York City.

'84.

CHAS. F. PARKER is one of the firm of Filley, Parker & Filley, Electro-Platers of Aluminum and Aluminum Bronze, by the process of the Harvey, Aluminum Plating Co., 296-300 Oakland Street, Brooklyn, E. D., N. Y.

THE SAD NEWS comes to us that Chas. W. Thomas has been bereaved, by sudden death, of his wife and child.

A. SAUNDERS MORRIS has resigned his position with the Westinghouse Electric Co., and is now connected with the Thomson-Houston Electric Co., Boston, Mass.

'85.

WM. T. CLERK is at Santa Barbara, Cal.

LEWIS N. LUKENS is Agent for the Conshohocken Tube Co., Manufacturers Wrought Iron Pipe, 22 Gold Street, New York City.

BARTON H. COFFEY has recently been granted a patent for improvements in a gas engine.

RICHARD H. RICE resigned his position as Chief Draughtsman with E. D. Leavitt, Jr., Cambridgeport, Mass., on February 1, 1891. He was compelled to take a rest, as the close application to the confining work of the draughting room had begun to undermine his health. A trip to Maine and subsequently to Cuba has enabled him to recuperate sufficiently to resume work shortly. His address for the present is No. 5 Ellsworth Avenue, Cambridge, Mass.

'86.

WM. W. RANDOLPH is in the Engineer's Department of the Kansas City Gas Light and Coke Co., Kansas City, Mo.

'86.

Mechanics of March, 1891, contained the following account of the Buffalo Electric Railway, which was constructed by the Field Engineering Company:

"The Field Engineering Company of New York, through its Mechanical Engineer, Mr. E. F. White; its Constructing Engineer, Mr. E. J. Cook; and its Superintendent of Construction, Mr. J. B. Craven, has done some excellent work—the construction of the Buffalo Electric Railway. The lines of this company aggregate 106 miles of single track. The number of cars to be operated in the aggregate will be about 300, which will be mainly 32 and 34-foot eight-wheeled vestibule cars.

"About one-third of the line will be center pole construction, with tracks spread to 6 feet; the remainder will be cross-suspension. In all of the construction the best type of iron poles will be used. In order to make the line more secure, and remove any possibility of cumbersomeness in the overhead work, the feed wires in all portions of the city, except the outlying districts, will be run in underground conduits, the main trunk lines being run from the station in three directions, out of which branch lines are taken as the different systems are crossed, and divided up. By thus placing feed wires under ground, we not only add to the reliability of the system in bad weather, but remove many of the prejudices against the same, leaving only the trolley and guard wires overhead.

"The present power installation is composed of six units, consisting of cross compound engines furnished from New York by the Ball Engine Co.; the capacity of these engines is 250 horse power, and each one drives a 225 horse power Edison generator. The plant will be started off with this capacity, and the remainder, up to 5,500 horse power, will be added as required. The foundations, however, are only installed for the present installation, and the flooring is over this part only, the remainder of the room being left empty down to the concrete bed for the rest of the plant to be installed as desired, as this plant will be composed of eight units of 500 horse power vertical compound, each one driving one or two generators."

'87.

C. A. Lozano is located at the works of De la Verge Refrigerating Machine Company, 138th Street, East River, in the capacity of engineer and draughtsman. He has been South for some time on business for the company.

Crawford Wheatley is General Manager of the Americus Refrigerating Company, of Americus, Ga., a new company, which he was mainly instrumental in organizing, and is at the same time General Manager of the Americus Construction Company, manufacturers of dressed lumber and building material.

The Refrigerating Company is building a 20-ton ice plant, which will be ready for operation about May 1.

'88.

THORBURN REID contributed an article on "A Simple Method of Dynamo Design" to *The Electrical Engineer;* the article is published in the issues of February 4 and 11, 1891.

H. S. WYNKOOP is with the Edison General Electric Company, and is located at 112 Bush Street, San Francisco, Cal.

R. H. SMITH is in the employ of the Hale Elevator Company, 189 La Salle Street, Chicago, Ill.

H. C. GRISWOLD is Assistant Engineer of the Louisville and Nashville Railroad, with office at the headquarters of the Louisville, Cincinnati and Lexington Division, East Louisville, Ky.

LARZ W. ANDERSON is Assistant Superintendent of the Addyston Pipe and Steel Company, Cincinnati, O.

E. R. DAWSON is Transitman of the R. & S. Railroad, Franklin County, Va.

HENRY A. BANG is Engineer and Chemist for the Haskin Wood Vulcanizing Company, 40 Wall Street, New York City.

R. M. BLANKENSHIP has applied for junior membership in the American Society of Mechanical Engineers. He is located in the Nail Department of the Old Dominion I. and N. Works, Richmond, Va., and is superintendent of the works.

'89.

GEORGE B. MULDAUR is Associate Editor of *The Electrical Engineer*, 150 Broadway, New York City.

WALLACE M. HILL is in the Laboratory of the Weston Electrical Instrument Company, Newark, N. J.

ROBERT G. SMITH recently delivered a lecture on "The Growth of the Locomotive" before the Y. M. C. A., at Plainfield, N. J.

'90.

GEORGE L. TODD is with R. W. Hildreth & Co., engaged in the inspection of bridge material, and is located, at present, at the Carnegie & Phipps Steel Works, Pittsburgh. The New York office of the firm of R. W. Hildreth & Co. is at No. 2 Wall Street.

E. H. PEABODY is draughting for J. M. Mossman, 101 Maiden Lane, in the Department of Safe Deposit Vaults.

S. F. SMITH is in the Hoboken Ferry Repair Shops, 14th Street, Hoboken, N. J.

HENRY TORRANCE, Jr., is located at Carbondale, Pa., with the Hendrick Manufacturing Company.

A. B. MOORE is ship-draughtsman in the yard of the Samuel L. Moore & Sons Co., Shipbuilders and Engineers, Elizabeth, N. J.

COLLEGE NOTES.

YALE.—The average expenses at this college last year were as follows: Freshmen, $786.96; Sophomore, $831.34; Junior, $884.17, and Senior, $919.70. The largest expenses reported was $2,908. There were 119 elective courses open to the academic Juniors and Seniors. The year's catalogue shows a total of 1,645 students, as compared with 1,477 last year. The Senior Class has given $10,000 toward the fitting up of the new gymnasium. The Freshmen in the Sheffield Scientific School have invested $6.50 each in class canes. Hereafter the Glee Club will devote their profits to establish a contingency fund of $3,000 from which to pay running expenses. By a recent enactment of Congress, drill will have to be added to the military instruction hereafter given by Lieut. C. A. L. Totten of the regular army, in Sheffield School. During the last six months Yale has received bequests amounting to $700,000. Discontinuance of tug-of-war has been advised by the college physician.

PRINCETON.—A gift of over 30,000 pieces of pottery and porcelainware, illustrating the history and progress of art from the earliest Egyptian period down to the present time, has been received. Now that the holidays are over the base-ball nine will go to the training table. Keefe, of New York, has been engaged to coach. Gymnasium work will soon be required of those who are seeking positions on the football eleven next year. A new hall, costing $150,000, the gift of a New York lady, will be erected in time for commencement exercises. Since 1876 Princeton has sent out seven exploring expeditions to the western part of the United States in the interest of the natural sciences. This year an expedition will be made to investigate the Gulf Stream.

HARVARD.—The minerological department which Harvard will soon have contains the finest collection of meteorites in the world. The value of this portion of the collection alone is estimated at $1,500,000. In the spring games another attempt will be made by Downs to break the quarter mile record. The Faculty has granted the petition of a Japanese student there who wishes to substitute Chinese and Japanese for the Latin and Greek of the required entrance course. About $32,000 are spent yearly for athletics. The Freshman crew are to have a new shell, to cost $600.

CORNELL.—Attempts have been made to raise $4,000 for the University and Freshman crews, but so far they have met little success. This college has an annual income of $500,000. The Faculty refused to allow the Sophomores to banquet out of town. Too much class spirit caused the decree. Ten per cent. of the graduates last year were women, and they carried off 60 per cent. of the honors. A gymnasium annex, costing $20,000, and a $65,000 law building, will be added by next year. The trustees have decided to reduce the tuition fee to $100. In all the technical

courses, however, the fee is unchanged. A student hospital will probably be built this year. The college library contains 140,000 volumes, including a superb set of works on French history, said to be the finest outside of France. Some time ago the Alpha Delta Phi House was damaged by fire, but the loss was covered by insurance.

CHICAGO UNIVERSITY.—This college promises to be one of the largest in the country. It will open October 1, 1892, having for its president Professor Harper, of Yale. "The classification of the teaching force is as follows: The head professor, the professor, the non-resident professor, the associate professor, the assistant professor, the instructor, the tutor, the docent, the reader, the lecturer, the fellow and the scholor. A striking feature of the plan is the division of the scholastic year into four quarters, each divided into two terms of six weeks with a week intervening each quarter. The standing of a student is determined from his term grade, from an examination at the completion of the course and from a second examination taken twelve weeks after the first. A student may take his vacation any one of the four quarters, or two terms of six weeks in different parts of the year. The courses of instruction will be classified as majors and minors, the former calling for at least ten hours of class room work a week, the latter four. All courses will continue six weeks, but the same subject may be pursued through two or more successive terms either as a major or a minor. No teacher is required to work more than thirty-six weeks in the year, and for any work beyond this he will receive extra pay or vacation. Anyone who has taught three years of forty-eight weeks each, or six years of forty-two weeks each, will be entitled to a year's vacation on full pay." The first official report of the university has been issued. It is proposed to make its scope very wide, and eventually to include preparatory schools, colleges of liberal arts, sciences, literature, practical arts, post graduate school, theological school, law school, medical school, and schools of engineering, pedagogy, fine arts and music. The directors decided to ask for $500,000 from Chicago citizens to erect buildings for the university.

YALE, Harvard, Princeton and Columbia have made arrangements for holding entrance examinations in Paris during the present year.

AMHERST.—This College has received $40,000 for the endowment of a Scriptural Chair. The new catalogue shows a total of 3,319 alumni, of whom one-third have been ordained as clergymen. A gift of $100,000 has been received on condition that $150,000 more be pledged. Amherst College was first opened in 1821 with 47 students. There are this year 352, 72 being in the Freshman Class.

AT Haverford College, Pa., a thirty horse-power engine was made in the machine shop. All the plans, drawings and castings for it were made by the students, under the direction of Professor Edwards. The engine will probably be used in connection with the system of electric lighting which has been planned for the college.

FOOT-BALL has been introduced in some of the German universities with great success.

THE students of Williams are taking measures to raise $200,000 for a chapter house, to be used in common by the fraternities represented in the college.

THIS spring ground will be broken for a new physical laboratory at Lehigh. There has been purchased for the Department of Electrical Engineering a Westinghouse and a Thomson-Houston dynamo and a Sprague motor.

IT is said that college journalism originated at Dartmouth in 1800, Daniel Webster being the editor of the paper.

THE bi-centennial of William and Mary College will be celebrated in 1893.

THE United States Government is putting up a $100,000 gymnasium at West Point.

NOTHING in this country more astonishes an English university-bred man than our college yells. He never takes the practice as a bit of American fun, but seriously sets to work to prove how even educated Americans follow the customs of the savage Indian, his war-whoop being perpetuated in the college yell.—*Mail and Express.*

THE alumnæ at Vassar have raised $40,000 to endow a Professorship in Astronomy.

THE University of Pennsylvania may take Princeton's place in the Intercollegiate Lacrosse Association.

THE Glee Club at Rutgers has discarded dress suits, and will hereafter, at its concerts, appear in gowns and mortar-board hats, English student fashion.

THERE are now eight club houses in New York City, representing the various college fraternities.

CANADA has 40 colleges ; Brazil, 45 ; while India can count 80.

THE Italian Government has issued an order that the English language shall be added to the courses in all the Italian colleges.

AT Rutgers' gymnasium exercise has been made compulsory for the two lower classes.

THE basement of Judd Hall, Wesleyan College, has been fitted up as a chemical laborarory for the Sophomores. It is now 93 years since the Glee Club was organized and its members for their initiatory trip took a lengthy tramp over the White Mountains.

THE University of Pennsylvania holds the championship in football in nsylvania ; Harvard, of Massachusetts ; Princeton, of New Jersey ; a, of New York, and the University of Virginia, of the South.

APAN has a ball nine composed of Yale, Harvard, Princeton, Columbia, University of Virginia men. A society of Yale alumni is being formed

VASSAR College has settled with the next of kin of John Guy Vassar by paying to them $146,000 out of the $650,000 bequeathed to the college by Mr. Vassar. There were eighteen next of kin, each receiving about $8,000 by settlement.

RESOLUTIONS signed by 1,360 members of the University of Cambridge protest against any movement toward the admission of women to membership and degrees in the university.

THE University of Michigan has professors and instructors to the number of 135.

HARVARD, Columbia and Cornell have each received a copy of the newly discovered manuscript of Aristotle on the Constitution of Athens.

AMERICAN Colleges derive two-fifths of their income from students, while English universities only one-tenth from the same source.

THE first gymnasium or college for women in Rome is to be opened April 1st, 1891. This is in accordance with the order of Minister Roselli. The grade and character of the new institution is to be that of the technical schools and the object is to enable young women to prepare themselves to enter the universities.

CHAPEL is no longer compulsory at Columbia, but students from all departments are invited to attend.

THE Faculty of Boston University have voted to allow work on the college paper, The University Beacon, to count as hours in the course, allowing four hours a week to the managing editor and two hours per week to each of his assistants.

ANNOUNCEMENT.

Beginning with Volume VIII. the subscription price of

THE STEVENS INDICATOR

HAS BEEN INCREASED TO $1.50 PER ANNUM.

Single Copies 50 Cents.

The STEVENS INDICATOR is the official organ of the Alumni and Undergraduates of the Stevens Institute of Technology.

As many of the Alumni of Stevens who are engaged in important engineering work and members of the Faculty pursuing scientific research are its regular contributors, the editors can promise that the INDICATOR will continue to rank with the most valuable scientific publications of the day.

Its high standard in the past is testified to by the fact that many of its articles have been republished by scientific journals in this country and abroad as well.

The date of issue of the INDICATOR is the 15th of the months of January, April, July and October.

To insure the appearance of articles in a certain issue, the matter for publication should be sent in not later than one month previous to the date of such issue.

THE STEVENS INDICATOR.

VOL. VIII. JULY, 1891. NO. 3.

COURSE OF LECTURES IN THE DEPARTMENT OF ENGINEERING PRACTICE.

BY PROF. COLEMAN SELLERS, E. D.

II.—THE MACHINE SHOP.—ABSTRACT.

FROM the drawing room—where ideas take shape on paper—tracings or blue prints from the drawings go into the machine shop by an indirect course, through the pattern shop, foundries, smith-shop, and through the purchasing agent to the markets for such material, finished or unfinished, as can be more cheaply obtained from specialists.

No one thinks of making the nails or wood-screws he requires; nor of drawing the wire he may need—if not a wire-maker. Nor indeed is it wise for a machine maker to manufacture his own cold or hot punched nuts, or in some cases even the bolts he may require, for the reason that manufacturers of these articles have perfected and cheapened their product to such a degree that we can buy what is required more cheaply than we can make without costly special tools. America is strong and is growing stronger every day in its line of special producers of parts common to all machines.

The machine shop dominates and controls all the other departments of the manufactory. I am about to talk to you of large establishments, not of a small jobbing shop, where a good handy workman, with a few assistants working with him, does whatever work may fall in his way, or makes in small quantities such articles as he may have chosen as his line of production.

The fully equipped establishment for building locomotives, or for making any other line of machines, requires a head to each of its departments. A foreman in the pattern shop who has enough

administrative work to do without working at the bench himself, lays out the work and directs the construction of the patterns, spending part of his time in the foundries. So he is required to direct the placing of complicated cores and informing the molders as to the management of the sweeps used in the loam work or dry sand casting. He has to mark all the patterns, and see them properly stored in the pattern loft. With 50 or more men at the benches, he will often require several helpers in this work, and is the better of a clerk to follow up the orders and the lists that come to him from the drawing room.

Pattern-making of itself is a good trade, and in the pattern shop are found many skillful workmen and men of very considerable inventive ability. It is in the pattern shop that men learn to be draughtsmen as well as skilled workers on wood; working to a degree of exactness far beyond what is expected of the best carpenters and joiners, yet capable of doing rough, cheap work when exactness is not wanted. The foreman of the pattern makers has to cultivate the faculty of guessing—for instance, how long it will take to construct the patterns for a new machine. In making up an estimate of cost, each department head must give his opinion of time required in his own department. A good foreman of the pattern shop is a man to be treated with great respect. In his department may be reserved some benches for the millwrights, who are mostly away from the shop putting up machinery, but who must have room for blocking out such woodwork as can be done in the shop; getting out framework; footing pieces for hangers; cogging gearing—*i. e.*, putting in and dressing to shape the wooden teeth of gearing that is to drive other cut iron wheels, etc.

In the use of wood and iron gear wheels, it is advisable in every case possible to make the wooden toothed wheel the driver, not the driven, for the reason that when the iron toothed wheel is made the driver and the strain of starting is great enough to break the wooden driven teeth the motion stops in the gap cleared away by the revolution of the iron teeth.

On the other hand, when the wooden toothed wheel is the driver, the teeth in the strain of driving the metal tooth wheel continually change position, and should one tooth yield another will advance and thus continue the imparted motion.

This may seem to many of little importance, but as the question of which of the two wheels shall act as the driver is one that is often

presented to the young engineer, he should be able to decide quickly and be capable of giving a reason for what he does.

I am the more impressed with the necessity of calling attention to this fact from my observation in Europe leading me to suppose that the advantage of making the wooden tooth wheel the driver has not generally impressed millwrights, as I have seen very many instances where the driving has been effected by iron tooth wheels, when in point of fact the only cases that it is in my opinion warranted is when a pinion of few teeth is made to drive a much larger wheel. I can conceive of instances in which the difficulty of cogging the small size pinion with wood would lead engineers to cog the larger driven wheel, but in any design of my own I should not under any circumstances whatever adopt a device or a system of gearing that would require the iron toothed wheel to be the driver.

These men, the millwrights, are usually under command of the foreman of the machine shop or the superintendent of the whole work; and if one millwright is called the foreman of the gang, he is a working foreman, working on the important jobs and holding a position of great responsibility. They have much rough work to do, and sometimes have to put in long hours in case of break-down jobs.

I tell you of these men that you may learn to appreciate their merits. Your attention might be called to the career of men who have risen from the ranks of uneducated workmen, with none of the advantages you have enjoyed in school, and who now stand high in their profession, as masters, their chief merit being in their wonderful industry and their readiness to do what had to be done totally regardless of themselves or their own comfort. Ability they must have, and integrity too. These are indispensable qualifications with the expenditure of money in works of public use or in private enterprises. The men who manage large numbers of men to the best advantage in manufacturing, are those who understand their business and can lead and direct, and who are able to appreciate the ability of their employees, The foreman or superintendent cannot be unjust to anyone, but he must keep each up to the mark by strict supervision, either directly or indirectly applied. The secret of making men do their best is to have everything done in an orderly, systematic way, with cleanliness and order in the shop and in all that belongs to it. The best work cannot be expected to proceed from slovenly conducted shops. Confusion and disorder are synonymous

with loss of time. With a place for everything and everything in its place, no time is lost in idle searching for tools or what is wanted.

So far as management of men under you is concerned, what is right in one department holds good with all in degree according to the class of men you have to deal with. I have had abundant opportunity to judge of methods of shop management in this country and out of it. In America we have the advantage of dealing with men who by education and by prospect in the future are far ahead of many of the poor workmen abroad who can neither read or write, and who have no hope in the future for any lot better than that to which they are born and to which they are bringing up their own children.

I have visited manufacturing establishments where, for want of proper sanitary precautions, men, women and children are condemned to work in an atmosphere so foul and unwholesome that I have been cautioned not to more than glance into the room; where, I am told, those who work there seldom last more than ten years.

I remember in one machine shop, a basement room, fully 200 feet by 200 feet, with the ceiling not over 8 feet above the floor; this room, lighted day and night by gas, with turning lathes packed so closely together as to barely leave standing room for the workmen, and scarce room enough for those who carried the rough metal in and brought out the finished work, getting through the crowded mass. In this room men worked ten hours a day, and went to their homes with their tired hands and faces black with the grime of the day of toil. Contrast this with the cleanliness and order of the great workshops in America, where men come clean to their work and go home with washed hands, the embodiment of self respecting citizens.

Give to each man the means of keeping order, and a place under lock and key where he can secure such tools as he is responsible for. Give them all good washing rooms, and let the shops be well lighted, warm enough in winter, and as cool by circulation of air as they can be in our hot summer. Let it be someone's duty to keep the floors at all times clean by sweeping; let all the waste product, the chips and turnings, be removed daily and disposed of in bins for their future use. An orderly machine shop cannot exist without an orderly tool room, and well administered store houses for the rough and finished stock.

A few words about the tool room. It is here that all taps, dies, reamers, boring bars, stock of files, and all the thousands of things

needed in the conduct of the shop, are kept in well-arranged racks, on benches, or in drawers, each item having a place for itself and each marked with metal or painted name or number; at each place for a tool let a projecting pin be ready to receive the workman's check.

The check may be a brass disc about $\frac{3}{4}$ inch diameter, with a hole $\frac{1}{8}$-inch diameter near the circumference, and on this disc or metal check is stamped a number. This number is the number of the man, and each workman is given a certain number of these checks, strung on a split key-ring; and with these 10 or 12 checks he is charged, in conjunction with a card mounted on wood, say 4 by 5 inches, upon which his list of tools is written; say, one monkey wrench, one hammer and what files he may require and other such tools as he must have by him, not neglecting one bench dust brush, one file card, etc. He is given the tools named with his card and his number, and he has a closet or drawer with a good lock and key to keep his tools in. When he requires any special tool, any tap or set of taps, reamer or other tool, he applies to the tool-room for what he wants, and, in place of the tool, leaves his numbered brass check; this is hung on the pin at the rack from whence the tool was taken, and a note always is made of the circumstance by the tool-keeper. He is required to note that the tool given to him is in good working order, and it must be returned after use in the same condition, save from the effect of careful usage. Breakages must be accounted for to the foreman, who is to say if carelessness warrants the man being charged with the value of the broken tool.

This system once tried will be continued; but its perfection requires a second separate room, in which all tools are repaired and resharpened. The workmen in the shop have no access to this room or to the tool room; the tool-keeper gives the returned tools to the sharpeners and then replaces them in their racks.

No general rule can be laid down to cover all cases; the character of the manufacture must largely govern the arrangement and extent of the storage department.

The introduction of modern tool-grinding machines, which enable every tool, every drill, every planing or turning tool to be resharpened in the very best way, and made according to the highest type as regards form of cutting edge, may be thought a needless refinement, and taking away from the workman his skill as a dresser of his own tools.

Let me tell you what Charles Holtzapfel says, in Vol. II., p. 28, of his admirable three first volumes of "Turning and Mechanical Manufacture," about turning tools: "It must be additionally borne in mind that however ponderous, elaborate or costly the machine may be, its effectiveness entirely depends upon the proper adaptation and endurance of the cutting tool through the agency of which it produces its results."

At the date this was written, Willis and others were experimenting on the best form of cutting tools, and from that time until now the work of experimenting on form has been going on with results that lead us to feel sure we can only reap the advantage of such knowledge by making the improved forms universally applicable by all classes of workmen. We cannot hope to make every one who uses tools an adept in this knowledge, but we can give him good, well-shaped cutting tools to work with, by means of tool-grinding machines, that dress each form of tool to shape and angle of cut and clearance by means of formers or modes that guide the grinding.

In one large steel works, where locomotive tires and axles are made in quantities, as also wrist pins turned out finished, mathematical formulas have been worked out to give, not only the speed of cut but the exact feed depth of cut, and durability of tool under the work, that will result in the greatest economy of output; but this subject is worthy of a lecture itself, and is now only mentioned as indicative of what is required in shop management.

The great problem of the day in machine work is to make parts of machines interchangeable with the greatest exactness and with the minimum of cost.

This subject calls for much thought, and a full knowledge of the theory and operation of cutting tools as well as the methods of securing perfection with the minimum of purely manual dexterity on the part of the operatives.

It is in the United States that an important principle in finishing metal surface came to be known and appreciated. The history of this discovery must not be neglected, as its history or cause of its adoption points to its utility.

The late Mr. Asa Whitney, of Philadelphia, made the important discovery that chilled cast iron (on the tread) car wheels were stronger if freed from the internal strains due to unequal cooling. He found that such wheels treated in the manner common to the

manufacture of glass utensils, namely, by annealing, were freed from internal strain. He, in undertaking to manufacture wheels on a large scale, desired to also fit them to turned axles. He also wanted to do this work with cheap, unskilled labor. The problem presented was: How can the eyes of the wheels be bored so accurate to size as to insure perfect interchangeability of parts regardless of time? Thus, a wheel bored to-day must fit an axle turned ten years ago, if required. The problem was presented to machine tool workers for solution.

Naturally, their study of this subject led to the conclusion that the sizing or finishing cutter if given the least amount of work to do, will last longer to size than if made to do more work at each cut, or to continue for a longer time taking a light cut owing to the slowness of the advancing rate of feed.

When a boring machine with one rate of feed only was used for both roughing and finishing cut, it was found that no matter how little work in depth of cut was left for the sizing cutter to do it would soon wear out of size from too much time spent in passing it through the hole being bored. This led to the ruling idea of the principle. Take out the mass of the metal with a strong tool, deep cut and fine feed, but finish with a light cut but very coarse feed, so as to hurry the cutter through while boring the finishing cut.

Four cutters in a $4\frac{1}{4}$-inch hole may be driven through the wheel, with say $\frac{1}{32}$ inch to each, or $\frac{4}{32} = \frac{1}{8}$ inch to each revolution, or even faster, but the four finishing cutters—*i. e.*, the two ends of two cross cutters, should each end take $\frac{1}{4}$-inch feed or 1-inch feed to each revolution. Thus, with the wheel making 16 revolutions per minute should go through the 7 inches of depth of hub in less than half a minute. It is by this process that one man has been able to bore, on one machine, 100 car wheels in one day of ten hours, and all to size.

As soon as this important fact, the advantage to be gained by light but very wide finishing feed, was known, the same idea was carried out in all turning, boring and planing operations. This is why American planing machines finish with broad feeds, and perfection is obtained with great saving of time.

To dress tools for machine work, so as to do this work well, requires mechanical automatic tool-dressing machines; with them tools are dressed so as to finish at one cut surfaces 3 inches wide, requiring an accuracy in tool grinding not attainable by hand tool-grinding on an ordinary grindstone.

When machines are to be built with interchangeable parts, all the improved methods of working to size, and to exact size, too, must be carried out. In England many shops are provided with cast-iron plane tables for use in laying out work. Castings and forgings, all painted white, are brought to these tables where special men gauge them, centre them, and mark with lines the surfaces to be dressed on the machines.

In the United States special jigs or tools to hold the pieces are provided, as also gauges to which the work must be fitted, all so made that one set will answer, not only for the gauges to which to work, but may be made to hold the piece for some other cut. This is exceedingly important in relation to small pieces that can be readily handled without the use of cranes, and applies specially to the construction of machine tools and work of such character. The so-called jigs are fitted with supports for the drills and boring bars, all bushed with hard metal so that the piece, if it requires to be bored for shafts to pass through these boxes, can be at once placed upon the proper machine, and the jig or template will guide the boring tool and bring the shaft borings parallel, and at proper distance one from the other to suit the gear wheels that are to be used in connection with them.

In such work as building turning lathes, planing machines, sewing machines, and, I might even add, type-writers, it is possible to have all the boring done by guiding templates, and this also can be carried out in large pieces such as the frames of locomotives. I have found it to pay well to spend upon these adjuncts to the work that is to be done very large sums of money, thereby insuring greater accuracy and tending towards interchangeability of parts.

In regard to the subject of interchangeable parts of machines, it will be well to bear in mind that with all such work there must be commercial limit to the accuracy. Absolute accuracy is impossible; we cannot obtain it, and we must be satisfied with that which can be called commercial accuracy, or what will answer the purpose in the most satisfactory manner and at the least cost. Thus, for instance, in fitting plain surfaces together the use of the surface plate and the scraper to reduce them to a plane (a principle that was first prominently brought to notice by Sir Joseph Whitworth, who made sets of surface plates to be used in reducing the plain parts of machinery to a perfect surface,) is carried out in all large workshops, and there are very few but that have facilities for repro-

ducing their own surface plates. But in reference to the degree to which scraping can be carried towards this perfection, you will find that it depends largely upon the area of the surface worked over. The large scraped surfaces for slides of engines, for bed-plates of lathes and planing machines, are usually considered well done when parts of contact are about ¼ of an inch square, and not separated over half of that amount.

This particular appearance that I am now alluding to is that produced upon a plain surface of metal when a surface plate has been rubbed over it and left the mark of its own contact, usually a little fine red lead or other coloring substance being used with the oil that covers it.

The process of scraping you have been taught in your regular instruction in your school; this is only to guide you in what is considered the commercial perfection of finishing by scraping. You will, in selecting machinery or buying machinery for your use, such as machine tools, find in some cases that this scraped appearance on the flat surface has been reduced to a wonderful degree of beauty and accuracy in the tools, as if the scraping cuts had been laid out in squares, giving a checker-board look to the surface. I would caution you to beware of all such work, because in perfect scraped work there can be no such regularity at all, it must be an absolutely broken surface of accidental high places taken off by the scraper. Machines that have this exceeding regularity of surface, when they come to show the effect of wear, may be found to touch each other only at points very distant one from another, thus exposing the deception of these so-called scraped surfaces.

The management of workmen calls for administrative ability of high order, and can be forcibly expressed by the short word "tact." There are men useful in their way who are classed as laborers, who, when they have the chance to do better, can be made into skilled workmen, if the trades unions will let you alone in your endeavors to make use of them.

Give a trained mechanic one kind of work to do continuously and he will soon tire of it, if it be something that requires only some part of his more extended skill.

As an example, boring car wheels, turning car axles, are jobs that call for men educated to that work from the laboring class, and such men will do more work, and do it better, if provided with proper appliances and paid by the piece, than skilled machinists.

It is when you come to use this kind of help, the trades union men, the Knights of Labor, etc., step in and say you must not attend to your own business in your own way. How to meet these difficulties will be an important part of your education if you are to be managers of men.

It is by paying for work by the amount done, and not by time, that you can accomplish your purpose, and do it well, too, if you go about it in the right way.

Every branch of industry will call for a different system for piece work, but some general rules may be laid down. The opinion holds with many that the best work can only be done by men who are paid for their time, and not induced to hurry out too much work as when paid by the piece. My experience leads me to the belief that better and more uniform results can be obtained by the piece system, when you can make each workman the inspector of another's work. You must plan to prevent any man hiding bad work himself or having a fellow workman hide it for him. Just how to do this will depend upon what is to be done.

Good workmen must be encouraged by permitting them to obtain high wages for the increased product of their labor. Any shop system looking towards division of a percentage of profit among employees does well when there are profits to be divided, but the average workman feels aggrieved when prices fall, dull times come, and the manufacturer, if not losing money, is obliged to sell at cost to keep his place going and to avoid a great reduction of his organized force of operatives. They are willing to share profits but are unwilling to share in losses.

In all new enterprises, all new things made, there must be a beginning, when the workman and the master are learning how to do the most work in the shortest time. So long as the thing is made by day work, it is to the workman's mind not desirable to do any more per day than he can do with personal comfort. Give him a chance to earn more per diem by piece work, and he will, in all probability, do only so much more as will give him all he dare claim without showing just how much more he could really do, fearing to court reduction by over profit.

It will be your business, or that of your foreman, to plan methods of economy, and to become well informed as to what can be done either by hand or machine tools. In the case of tool work, you can establish speeds of cut, and the utmost that can be accom-

plished is a matter of calculation. With full knowledge of what can be done, make the piece work prices what will enable a good steady workman to earn high wages, and let him feel confidence in you. Perfect confidence once established, will go a long way towards helping you to rates fair to both parties.

To insure good work, establish as a rule that work done wrong, either in size, that is to the given dimensions (and all work should be done to gauge, not to this or that pocket rule), or incorrect in form, by one workman, say in what we may call his cut, if not reported as wrong by the second hand who has to use the work done by the first, the fault, or fine, or work paid for will be by the second, who has used what he should have discarded, and so down to the final inspection of the work.

If one man has put work on a piece, so spacing his cuts as to leave too little stock for the next cut, he is to bear the brunt of the loss, either by fine or other system of preventing loss beyond the mere loss of time.

Each man must feel that he is putting work on valuable material that must be made to serve the purpose for which it is intended. Tickets should be issued to each man, who should have a fixed wage by the hour, not by the day, and then prices per cut or job set, which will enable him to claim a profit beyond his rate per hour to be paid upon the completion of all the work on that part. I have seen this work very well, and to result in perfect satisfaction to both parties. Payment by the hour is in anticipation of all rules and regulations governing the hours per day of work.

In dealing with men, it is well to start with the idea that each man is to be independent of all others, and not as a part of some society or organization. I cannot say that this independence or individuality can be established among all kinds of workmen in all trades. It can be among machinists, among smiths, pattern-makers and molders.

I have tried the experiment in piece work, to give one man a contract to make some one thing; say, the connecting rods for locomotives, and I have found it work badly both as to cheapness of output and quality of work. A better plan is to divide the work according to cuts and let the setting up or assembling be done by one who has no control over those who get the work ready for him. His chance to make better wages by reason of the tool work having been well done, leaving less for the finisher, will make him particular about the character of the work he accepts.

The moment you recognize the right of men in or out of your workshop to dictate to you in any respect, that moment you are laying the foundation for endless trouble.

If you have foremen and under-foremen, deal with your men through these under-heads, sustaining them in their places; and by being just to them, insist on their being the same to those below them.

Never to do yourself what some one else can do for you will enable you to accomplish more than if you devote your life to petty details and meddling management that interferes with and discourages those who should relieve you of this detail.

The business man who thinks he must write all his business letters himself, and even take the press copies so as to insure the least waste in the pages of his copy-book, and thus, too, insure his full knowledge of the business, may seem to you a fabulous being, but I have seen examples of this *genus homo*, and have seen just how such a man, with his nose to the grindstone, was ridiculed by his subordinates, if not cheated by them, too.

The selection of machine tools for the prosecution of any work that you may have to do is a matter of great importance. It is wrong to expect to find all makers of such machines producing similar quality of work of the highest order, or that the product of the different establishments will each do the same amount of work. You will err if you think that any machine tool regardless of quality is good enough to do rough work with, and that cheapness in first cost or low price should be the chief guide in the selection of the machinery required to equip an establishment.

I cannot too strongly advise against the practice of persons unaccustomed to machine tool building attempting to make their own machine tools, or even special ones for special purposes, except in some of the simplest cases. I have known of many failures brought about through managers thinking to economize by making their own lathes and planing machines, drill presses, bolt cutters and the like. There have been notable instances of establishments erected to produce a certain kind or class of machinery, where it has been very important to secure an equipment of tools to do the work as soon as possible and as efficiently as possible. Thinking to have them better adapted to their purposes than would be possible if bought in the open market, the manager has begun by making what he wanted, and while so doing he is losing

valuable time, and perhaps losing *the* time when the machine that he was to produce by means of the tools might have been floated and have created for itself a good market.

Men who have made a life study of machine tool building, with all their vast experience can at the best only satisfy in part their ideal of perfection. This is particularly the case if they aim at high class work; between such tool builders and those who make tools that can be sold cheaply, regardless of quality, there is a great space. It will be part of your education to judge between good and bad work, between machines well designed and capable of good execution and those that are less costly, but dear at any price. The wise manager who is able to equip a shop fully, and has the money required for that purpose, should look more at quality than at so-called low price. A machine tool that will enable an ordinary workman to do even only 10 per cent. more work per hour than on some other similar machine will be worth very much more in the long run.

I was foreman of a locomotive building establishment many years ago, and was compelled to use turning lathes built by my employer. He had two establishments ; one for building locomotives, another one where sugar machinery, stationary steam engines and some few machines, tools which, at the time that he began his work, could not be very well found in the market. In one particular instance a lathe that would swing 30 inches in diameter, which was the most powerful lathe I had at my disposal for the purpose, could at the best with a high-priced workman turn out only four truck axles in ten hours. It was no easy matter to convince my employer that the fault rested with his type of turning lathe. When I offered to double the work with a well-built lathe of less nominal size and power, I had, before getting his consent to the purchase of one single machine, to exhaust in his presence all possible efforts to have more work done on the tool that he had given me to work with. I knew very well that could I get that one lathe which I asked for I could not only double the product but even quadruple it. Now it does not require any very complicated calculation to show that if for the work that is to be done it requires four machines, each one operated by a high-class workman, when that same work can be done by one single machine with a less costly workman, there would be a saving not only of the space that the machines would occupy but a saving of the wages of these men who are dispensed with, and the increase of the output.

It is this ultimate and greatest possible output of work that is the end and aim of machine tool builders to bring about. It is upon a possibility of their machines accomplishing more work that they are able to push their sale in the market. It is not only necessary that machine tools should be able to do all that is required of them as far as quantity of work is concerned, but also that they should do that work well, and that the wear and tear should be the lowest.

Up until quite recently, and probably the fault still exists, you will find upon analyzing the construction of one single machine tool, take the lathe for example, that in the design of the most of them where there is a cone pulley in the live head actuating the spindle either directly as a single geared lathe or by back gearing as a double geared lathe, or by a third set of gear attached to the face plate, what is called a triple geared lathe, that the speeds due to each lift of the cone are not always in geometrical progression. You will find, in nine cases out of ten, that the series of speeds incident to the cone modified by the gearing are not continuous but overlap one another. Thus, that with the back gear in, you get, probably, the same speed as the lowest speed of the cone employed alone; while in point of fact if there are five lifts to the cone pulley, and the lathe is a triple geared lathe, there should be three times five or fifteen distinct speeds, each one decreasing in velocity by a certain fixed geometrical rate of progression from the fastest to the slowest speed. If the lathe will not accomplish this it is faulty in design.

It would be impossible for me to give you an exact description of each machine tool, and say in what respect I considered one form or design better than another, but I would be remiss if I did not call your attention to such palpable errors in design as that which I have instanced as obtaining with the cone pulley of the turning lathe.

All parts of machine tools should be made interchangeable. It is quite feasible to have every lathe of the same nominal capacity capable of carrying the same size and taper in fit of the hardened centres, and this part of the lathe should be so well made and so correct in construction as to permit absolute interchangeability of centres; so that when one becomes worn it can be replaced by one taken indiscriminately from a lot in the tool room.

Endeavor to obtain it you can, from tool makers, their illustrated price-lists. Read their arguments as to the merits of their

products, and then try to discriminate and judge of the merit of the claims that they set forth.

I happened a short time ago to come across a very entertaining and useful book called "Aids to Engineering," published by Spon & Co., in which some most valuable advice is given in reference to the selection of machine tools; and I was forcibly impressed with the error that was made in most vertical drilling machines, by reason of not arranging a counter-balance to prevent the drill spindle dropping if any defect in the work permits the drill to fall. All drill spindles should be counter-balanced up. Further on, in reading the same book, I find a description of the American twist drill, where it is said that they are rather tender on the cutting edge, and drill presses using the twist drill should always have the drill spindle counter-balanced up. Here, a principle which I hold as being absolutely essential to all drill presses, is only brought forcibly to attention when it is supposed to deal with one special form of drill.

You should familiarize yourselves with the possible rates of feed with speeds of cut, and note in the purchase of machine tools whether they will give you what is required for the class of work they are expected to do.

Up to the year 1870 or '72 the greatest improvement that had been made in boring locomotive cylinders had resulted in the production of probably one cylinder to each lathe in from one and half to two days' work. It was not an unusual thing to spend twenty hours on one cylinder only 16 inches in diameter and of the usual stroke of such an engine. When called upon to design a machine tool specially for boring locomotive cylinders, the calculation was made as to the rate of cut and possible feed, on the principle that while the roughing cut was being taken by four cutters acting conjointly in the boring bar, the sinking heads of the casting might be cut off by a separate tool, and the ends of the cylinder faced up ready for the cylinder heads. Afterwards, the finishing cut might be hurried through much more rapidly by taking a lighter cut and a more rapid feed. For a 19-inch cylinder, the calculation of possible time required to bore a cylinder was only three hours instead of twenty hours, as had been the habit before. A machine was built upon this theory of time; a machine now well known and in common use, but first exhibited at the Centennial Exhibition, the first one being for the Rogers Locomotive Works. That machine and all since have been capable of boring a cylinder in three and a

half hours, so that practically, separating the facing from the turning part, it is an easy matter with one machine of this kind to satisfy the requirements of one locomotive a day, so far as cylinder boring and turning is concerned.

Make up your mind exactly how much time the work should take, and then examine your machine tools to see if they are designed for strength, speed and efficiency to do the work in the time you have calculated.

In every well-equipped tool room there should be a complete set of steel mandrels, which are hardened and ground to standard sizes. These mandrels must be treated with some care, and their further preservation can be insured by the use of simple forcing presses by means of which they can be pressed by screw or hydraulic pressure into the work that is to be carried by them in the turning lathes.

It should be a fixed rule in every machine shop that no mandrel should be driven into the work by blows of a sledge or hammer, even with the precaution of putting lead on the top of it, if it is possible to procure a forcing press for this purpose.

The simplest kind of forcing press can be made of two wrought iron uprights with a base plate and cross-head, using as the forcing power an ordinary hydraulic jack with a flat table upon the top of it, upon which to rest collars, the eyes of which collars are a little larger than the mandrel that is to be forced into the work.

The use of steel mandrels in the brass shop will save a great deal of expense and enable sizes to be maintained with the greatest precision. You will find it very convenient where brass work is to be finished interiorally to given fixed sizes to drill or bore the work smaller than the size of the mandrel to an amount which can only be ascertained by a little practice, then by forcing the hardened steel mandrel into the piece that is to be turned the metal will be stretched and will firmly clasp the mandrel and permit the work being done in the lathe with the certainty of its not coming loose during the turning operation. When finished the mandrel can be forced out in the same press that was used to force it in, and the hole will be finished interiorly as perfectly smooth as the exterior of the mandrel used in the work.

This operation amounts to a species of cold drawings of the piece. It makes the eye or hole in the work the exact size required; it insures a good finish to it, and entirely does away with the need of reaming out the drilled or bored hole with a standard reamer.

In the erection of buildings to be used as machine shops, when they are located in large cities, it is very important that the windows which give light to the room should be set, on the ground floor, so high above the pavement as to prevent the people outside from looking in as well as those inside looking out.

The high windows also serve the purpose of better lighting the work, and in some recent examples of erecting shops that have been put up, windows placed in the tall erecting rooms as much as 15 feet above the floor have been found to be much more efficient than those placed on a lower level.

The constant liability of workmen having their attention drawn away from their work by outside passing shows, and of passers-by stopping to talk, needs this care in the placing of the windows, as, also, it prevents the overlooking of the work by passers-by and actually makes the rooms more comfortable and better fitted for the work to be done.

The recent improvements that have been made in traveling cranes and also in swing cranes will present abundant opportunity for you to select what can the most readily serve in the equipment of a machine shop in regard to handling heavy pieces.

The recent introduction of reliable electric motors is likely to do a great deal toward the convenient equipment of machine shops, as it tends to do away with a great deal of the line shafting which has usually prevented the placing of cranes for handling the work.

I look forward to the time when these independent electric motors, or some other small motor, not driven by steam directly, will come to be applied to most of the large machine tools that are required, as, by their use, two important things are accomplished, one, the saving of space now occupied by belts and pulleys, and the other, the better regulation of the work and the ready continuance of special work by overtime, without having to run all the machinery of the shop for the sake of driving some special tool.

The model machine shop of the future will be one in which electricity or compressed air, or some other mode of transmitting motion, will play an important part, and it is in the equipment of such establishments that the knowledge that you have gained in schools can be put to good account and be made to yield an immediate profit, not only to yourselves, but to those who will seek to employ you.

ANIMAL, MARINE AND VEGETABLE OILS USED IN LUBRICATION—THEIR CHEMICAL REACTIONS AND THE METHODS OF DETECTION IN MIXTURES.

BY PROF. THOMAS B. STILLMAN.

[Continued from page 112.]

Viscosity.

THE viscosity or "body" of an oil is the first requisite in lubrication, and, generally speaking, the best oil is one that varies the least in its viscosity as higher temperatures are reached.

The introduction, in late years, of a large variety of mineral oils of high viscosity for lubricating purposes, and the large number

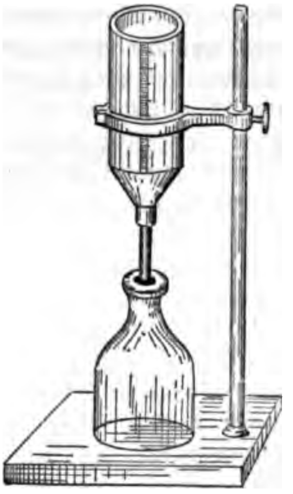


FIG. 3.

of compounds made use of to thicken these oils, has given this subject an enhanced value.

Standard simple oils, like lard oil, sperm oil, tallow oil, have a nearly constant variation in viscosity as the temperature of the oil increases.

The compounded mineral oils, containing thickening mixtures, "blown oils," etc., etc., present a different subject for examination, and no rule can be laid down for the increase or decrease of their viscosity at various temperatures, since many of the added substances show a high viscosity at normal temperatures and a very low one at high temperatures.

For this reason each sample of compounded oil should be tested for viscosity at various temperatures, and especially at the temperature at which it is proposed to use the oil in practice.

The first instrument for determination of the viscosity of oils was probably Schubler's (Fig. 3). It consisted of a graduated glass cylinder open at the top and drawn to a $\frac{1}{8}$-inch tube at the bottom. Having filled the cylinder with the oil to be tested, the time required for 100 cc. of the oil to flow out through the lower aperture was noted, and this figure compared with that obtained from water under similar conditions.

Thus, Schubler records, among many determinations, the following:

	Seconds at 15° C.	Seconds at 7.5° C.	Comparative Thickness with Water at 15° C.	Comparative Thickness with Water at 7.5° C.
Colza Oil.............	162.	222.	18.	22.4
Olive Oil............	195.	284.	21.6	31.5
Hempseed Oil.........	87.	107.	9.6	11.9
Castor Oil............	1830.	3390.	203.	377.
Distilled Water.......	9.	9.	0.	0.

The Penna. R. R. Co. viscosity tests are made as follows:

"A 100 cc. pipette of the long bulb form is regraduated to hold just 100 cc. to the bottom of the bulb. The size of the aperture at the bottom is then made such that 100 cc. of water at 100° Fahr. will run out of the pipette down to the bottom of the bulb in thirty-four seconds.

Pipettes with bulbs varying from 1¾ inches to 1½ inches in diameter outside, and about 4½ inches long, give almost exactly the same results, provided the aperture at the bottom is the proper size.

The pipette being obtained, the oil sample is heated to the required temperature, care being taken to have it uniformly heated, and then is drawn up into the pipette to the proper mark. The time occupied by the oil in running out, down to the bottom of the bulb, gives the test figures. A stop-watch is convenient, but not essential in making the test. The temperature of the room affects the test a little. The limiting figures were obtained in a room at from 70° to 80° Fahr. It will not usually be possible to make duplicate tests without readjustment of the temperature of the oil. Bullock & Crenshaw, 528 Arch Street, Philadelphia, can furnish the pipettes for making viscosity tests. They should be ordered as "P. R. R. Viscosity Pipettes."

These pipettes are in use by many other railroads in the United States.

A. C. J. Charlier (*The Engineer*, 1890, p. 205) recommends the following:

"An ordinary glass tube having a diameter of half an inch, tapering to a point at one end, and marked into divisions of one inch, will answer all ordinary purposes for testing the viscosity of an oil. The oil to be tested is to be placed in this tube up to a certain mark, and is then allowed to run out at the tapered end of the tube, and the time taken is noted. This is compared with the time taken by standard oils previously ascertained in the same tube, and thus the viscosity of the oil can be determined."

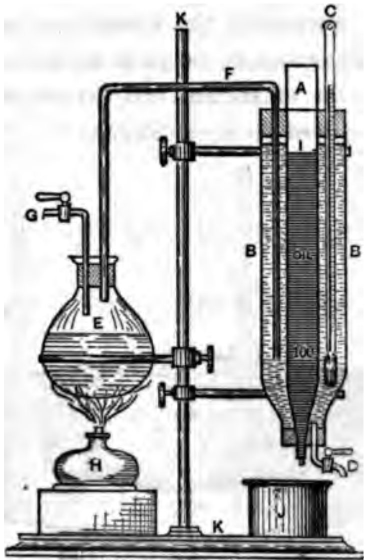
W. P. Mason (*Chem. News*, 1884) describes a viscosimeter for use at 15.5° C.

The viscosity of an oil, experience has shown, should be determined at higher temperature than the above examples indicate.

Wilson's apparatus (Fig. 4) was one of the first where heat was applied to the oil in the viscosimeter. CREW, (*Practical Treatise on Petroleum*, p. 363).

A is a glass-tube about one inch in diameter, graduated from 1 to 100, to contain about 100 cc. of the oil. *B B* is a glass jacket about three inches in diameter, filled with water, as shown. *C*, a thermometer indicating temperature of water in jacket. *D*, a small brass cock for withdrawing water from jacket. *E*, a glass flask for

generating steam to heat water in jacket. *F*, a glass pipe connecting the steam flask *E* with jacket *B*, delivering at bottom of jacket. *G* is a small cock for permitting an escape of steam in order to regulate the amount sent into jacket. *H*, a spirit lamp on a stand. *J*, a glass beaker to contain oil; and *K*, cast-iron stand, with adjustable arms, for carrying the apparatus.



VISCOSITY OF OILS.

FIG. 4.

The following table shows the determination of viscosity made by this instrument:

	RATE OF FLOW.		
	15.5° C.	49° C.	82° C.
Castor Oil	....	132	41
Tallow Oil	143	37	25
Neats-foot Oil	112	40	29
Rape Oil	108	41	30
Lard Oil	96	38	28
Olive Oil	92	37	28
Sperm Oil	47	30	25

Engler's viscosimeter (original form, Fig. 5) was constructed of metal, and consisted of *A*, a chamber holding the oil to be tested, *B* the water-bath, *C* a flask graduated so as to receive 200 cc. of the oil; *a*, *b*, thermometers; *e* the opening through which the heated oil flows out upon the withdrawal of the plug *d*.

In using this instrument the viscosity of an oil is stated in seconds required for 200 cc. of the oil to run into the flask *C*. Heat can be applied to the water-bath, and the viscosity determined at any temperature required up to 100 degrees C.

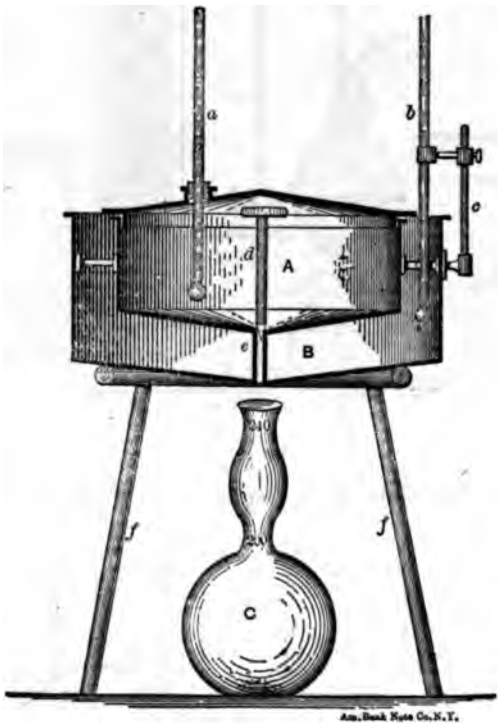


FIG. 5.

Engler recommends that all viscosities be compared with water, thus:

If water requires 52 seconds for delivery of 200 cc. into the receiving flask, and an oil under examination requires 130 seconds,

the ratio is determined by $\frac{130}{52} = 2.50$, the oil thus having a viscosity of 2.5 times that of water.

This instrument has been for many years the one generally used in Germany for viscosimetry, and in its later form (Fig. 8) still remains so.

Boverton Redwood (*Jour. Soc. Chem. Ind.*, Vol. 5, p. 128) describes a viscosimeter (Fig. 6), the general principle of which is the same as Engler's.

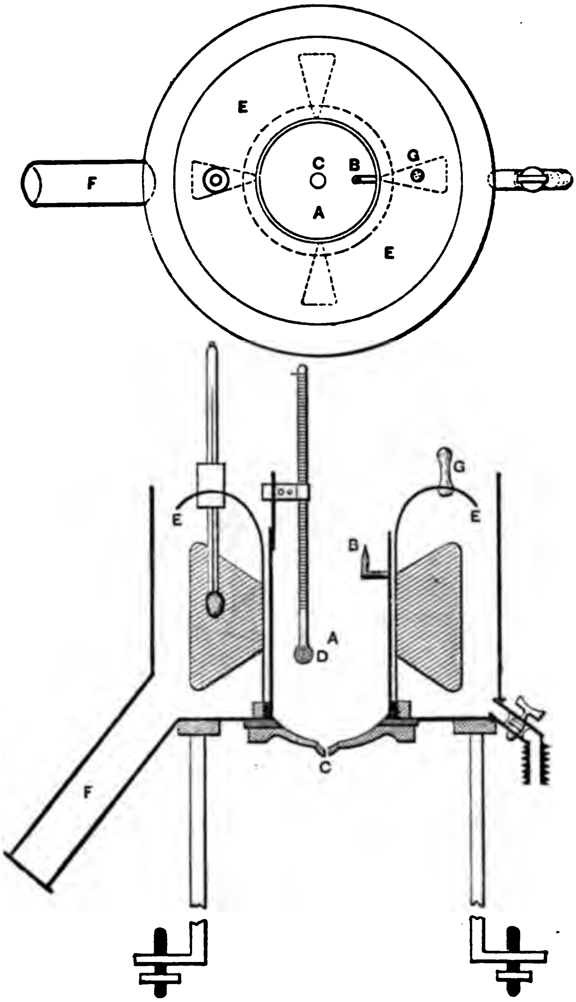


FIG. 6.

The tube *A* is of copper, and is $3\frac{1}{2}$ inches high by $1\frac{7}{8}$ inches wide. In practice, it is filled to a height indicated by the contact of the surface of the oil with a bent wire *B*. The orifice *C* is in agate. *D* is a thermometer; *F* and *E* the copper water-bath. The oil to be tested is maintained in the vessel *A* by a spherical plug inserted at *C*, which is withdrawn in the same manner as in the Engler apparatus. The bath is heated at *F*.

Redwood recommends the use of the two paddles for agitation and thorough mixture of water in the water-bath during the heating of the apparatus.

In practice, the viscosity of an oil is determined by the time required in seconds for 50 cc. of the oil to run into a containing flask placed under *C*. A number of determinations of viscosity at different temperatures by Redwood indicate as follows:

	At 15.5° C.	At 38° C.	At 94° C.
Rape Oil..................	540 seconds.	213 seconds.	58 seconds.
Sperm Oil..............	177 "	80 "	42 "
Neats-foot Oil...........	470 "	175 "	50 "
American Mineral Oil, sp. gr. .923..........	680 "	200 "	42 "

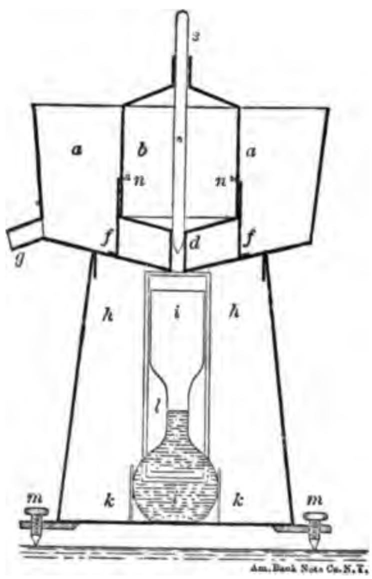


FIG. 7.

A. Kunkler (*Ding. Poly Jour.*, Vol. 279, p. 137) makes use of a modified form of the Engler apparatus to determine the viscosity at lower temperatures than normal, and also the solidifying point of the oils (Fig. 7).

a a, instead of a water-bath, is a reservoir to contain a freezing mixture.

75 cc. of the oil are used, the containing mark being indicated by the points *n n*.

c, the delivery aperature, is 20 cm. long, 7 mm. wide, and is closed by the tube *e*, which passes through the oil and the upper portions of the viscosimeter.

The extension *g* is used to allow the liquid to run out of *a*, and is closed by means of a rubber tube and stop-cock.

The upper portion of the apparatus rests upon the case *h h*, which prevents the warming of the outrunning oil at *d*.

50 cc. of the oil are run out into the measuring flask *i*, the latter being held in position by the supports *k k*. Two small windows, not shown in the drawing, are made use of in reading the delivery of the oil in the flask *i*.

Leveling screws *m m* are used to obtain a proper level in using the instrument.

The Engler Improved Viscosimeter is fully described in *Ding. Poly. Jour.*, Vol. 276, pp. 42–47, by C. Engler and A. Kunkler.

C. F. Cross, *Jour. Soc. Chem. Ind.*, Vol. 9, p. 654, in an abstract thus describes the apparatus (Fig. 8):

"The apparatus represented in Figs. 1, 2 and 3 has been designed to remedy the two defects of Engler's viscosimeter—viz., that in observations at high temperatures, the temperature of the oil varies sensibly during the running off, and the extremity of the efflux tube undergoes a gradual cooling.

"It is an octagonal jacketed air bath, 35 cm. high and 20 cm. broad. The feet *a* stand in the ring of a tripod in such a way that the level of the bath can be adjusted so as to control the level of the liquid in the viscosimeter itself contained in the upper portion of the bath.

"The heating surface *b* is arched; above this, and supported by the stand *c*, is the measuring vessel *e*, cut off from direct radiation from *b* by the asbestos plate *f*. Above this is the dividing plate *g*, upon which the viscosimeter is supported, the flow of oil passing to

e through the opening *h*. Circulation of hot air into the upper chamber takes place through *h*, as also through the four oval tubes *i* (Fig. 2). Through the cover plate pass the thermometers *u s*, the axis of stirring apparatus with the stop *t* for the efflux tube, and the funnel *v* for introducing the oil, heated to the required temperature in the apparatus *H* (Fig. 3). In the sides and cover, windows

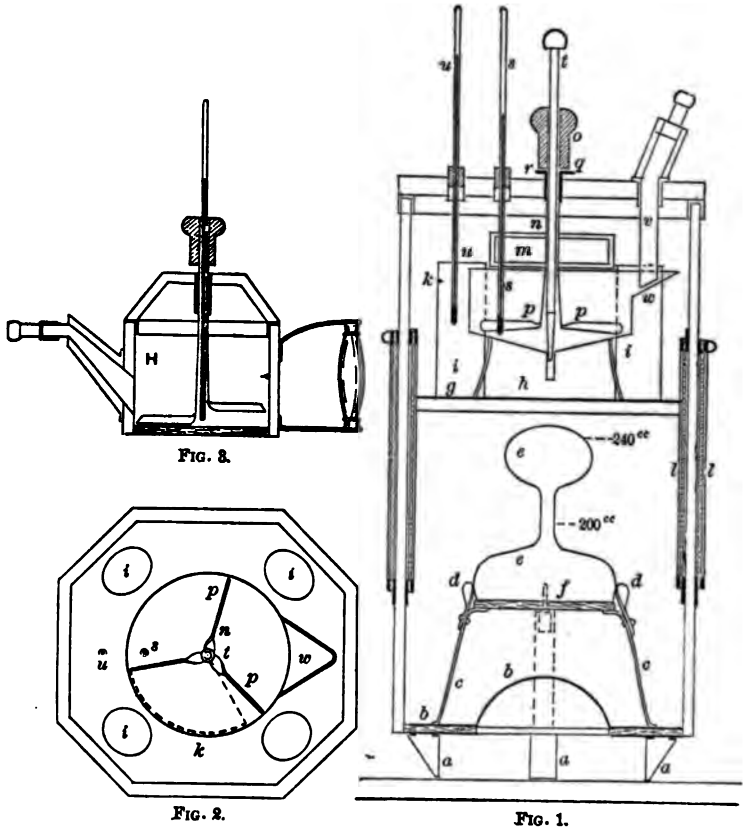


FIG. 8.

are let in the bath for illuminating, the former to permit observations of the level in the viscosimeter and the efflux of the oil into *e*.

"That the instrument fully satisfies the required condition of constant temperature, is stated by the authors in the following terms: Up to 100 degrees, the temperature in all parts of the

bath—heated with no change of oil in the viscosimeter—is equal and constant, excepting in the lower stratum of air in the viscosimeter itself, which is of course shielded from the general circulation. This difference disappears with the introduction of the oil. At temperatures higher than 100 degrees the air above the viscosimeter is of somewhat lower temperature, but the difference at 150 degrees did not exceed 4 degrees."

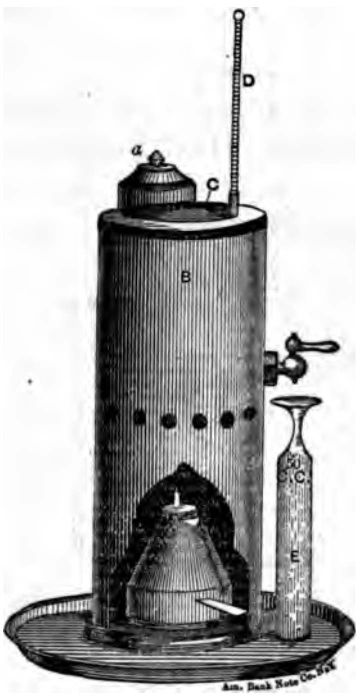


FIG. 9.

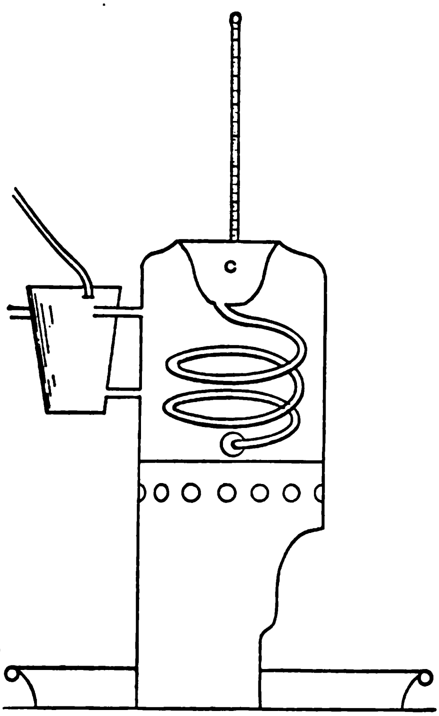


FIG. 10.

Tagliabue's viscosimeter (Figs. 9 and 10) consists of a basin *C* extending by means of the coiled tube to the outlet at the stop-cock on the outside of the vessel.

This is surrounded by the water-bath *B*, which has an outer chamber *a* connected by two tubes, and in which the water is poured into the water-bath. *D* is a thermometer, and records the temperature of the water-bath.

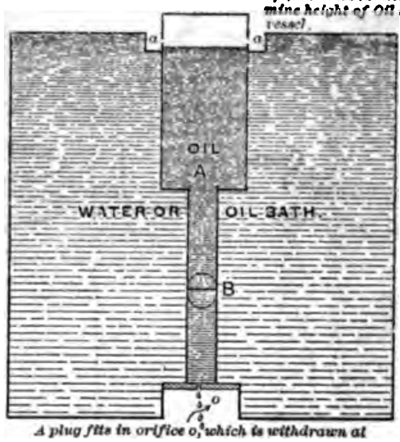
To test an oil, the water-bath is filled two-thirds full and heated by means of a small Bunsen burner or alcohol lamp. The top basin *C*, lined with wire gauze, is filled with the oil to be tested, and when the thermometer *D* indicates 100° C., the glass measuring flask *E* is placed under the faucet, which is opened with the starting of the watch.

When 50 cc. of the oil have run out and reached the mark upon the neck of the receiving flask *E*, the watch is stopped, and the number of seconds required noted.

The viscosity of the oil is stated in seconds.

This instrument has had a very extended use in the oil trade, but I have found it an exceedingly difficult piece of apparatus to

a,a, are holes to determine height of Oil in vessel.



A plug fits in orifice o, which is withdrawn at the instant the experiment commences.

SAYBOLT'S VISCOSIMETER.

FIG. 11.

clean when any particles of dirt have become lodged in the coil. This materially interferes with the flow of oil through the tube and gives false results. The basin *C*, as well as the coil, cannot be removed, as they are brazed to the water-bath. For this reason, and also when used at higher temperatures, the faucet being metallic and not heated to the temperature of the oil, the oil leaves the apparatus much cooler than the temperature recorded by the thermometer of the water-bath.

Saybolt's Viscosimeter.—This instrument, made use of by most of the chemists in the Standard Oil Company, is essentially as follows (Fig. 11):

"The oil to be tested is placed in the vessel *A*, which is enveloped in a bath of either heated oil or boiling water. The orifice through which the oil flows is at *O*. It is located somewhat above the bottom of the bath, in order that the oil, in issuing, shall not fall in temperature, as would be the case if the orifice was level with the bottom of the bath. (See also Engler's, Fig. 5.) The orifice is closed with a stopper, and the vessel *A* filled to the level of the overflow holes at *a a*.

The bath is then heated until the temperature of the test oil is at 100° C., or any higher temperature. The stopper is then withdrawn, and simultaneously a stop-watch is started. When the level of the oil in *A* has fallen to the mark *B*, set in a glass bull's-eye, the watch is stopped, and the number of seconds it records measures the viscosity of the oil. For instance, the time of flow of tallow, at 100° C., is 55 seconds. Hence, its "viscosity" is said to be 55. The quantity of oil which flows from the vessel *A* is about four cubic inches, or two ounces. The orifice *O* is $\frac{3}{64}$ of an inch in diameter. (Thompson & Bedford.)

Davidson's Viscosimeter (Fig. 12). [G. M. Davidson, Chemist, C. & N. W. R. R., Chicago, Ill.] This apparatus was designed, especially, for determining the relative viscosity of oils or greases when heated to the temperature of locomotive cylinders (250° to 350° Fahr.) The entire apparatus, except the glass portion, is made of copper and the joints brazed.

The oil to be tested is put into the cylinder *A* and cup *R*, which are connected through the stop-cock *C*. The cylinder *A* is also connected with the glass gauge through the tubes *H* and H^1, so that the height of the oil in cylinder can be seen. The bottom of cylinder *A* is covered by a brass plate, through which is bored a hole $\frac{1}{32}$ of an inch in diameter, which can be closed by the slide valve *E* held against the plate by a spring. The outside of the

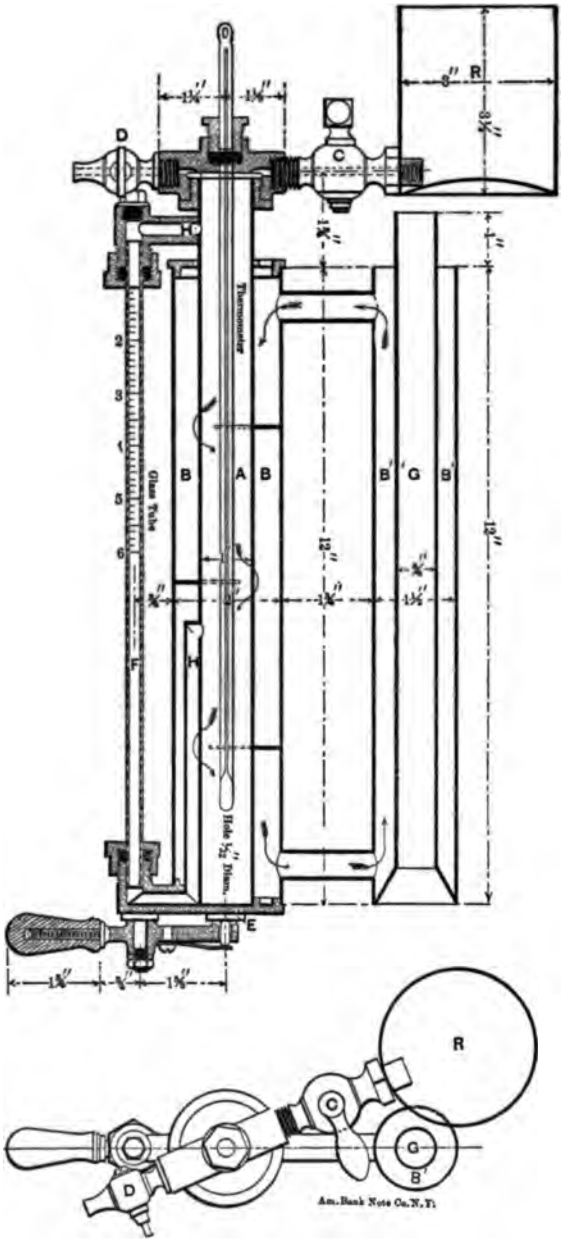

D
C
R
8″
3½″
Thermometer
Glass Tube
2
3
4
5
6
B
A
B
B′
G
B′
12″
12″
F
H
Hole 1/32″ Diam.
E
R
C
G
B′
D
Am. Bank Note Co. N.Y.

FIG. 12.

plate is beveled from the hole, so that the hole is in a very thin plate, and thus lateral friction is reduced to a minimum. A long thermometer is used, so that the bulb will be near the bottom of cylinder *A*.

The cylinders *B* and B^1 contain the lard oil bath that is used for conveying heat to the oil in cylinder *A*. Heat is applied by a lamp or gas burner at the base of cylinder B^1, and the hot products of combustion allowed to pass through the cylinder *G*. As the lard oil in B^1 becomes heated, it rises to the top of this cylinder, and passes over to cylinder *B*, down *B*, passing around the cylinder *A*, and back to B^1, where it is reheated and recirculated, as shown by the arrows. The oil in cup *R* is heated by the products of combustion escaping from the top of cylinder G, and in case of a high temperature by an additional lamp placed under the cup *R*.

When the oil under test in *A* and *R* has reached the desired temperature, the valve *E* is opened and the stop-cock *C* is adjusted to keep the height of oil in *A* the height desired, as shown by the glass gauge. A 100 cc. flask, which is immersed in hot oil, is then placed under the stream of oil flowing from the hole, and a stop-watch is started the instant the oil commences to run into the flask. When 100 cc. has been delivered into the flask, the watch is stopped. The number of seconds required for this is the viscosity of the oil under examination.

(TO BE CONTINUED.)

RAILWAY CAR LIGHTING.*

BY GEO. GIBBS, M. E., '82.

THE various methods employed for railway car lighting from early days until the present time have followed the process of evolution observed in other departments of railway work, beginning with the simplest and following in the direction of the more complex. A multiplication of detail and an amount of attention to operation which would have been considered quite inadmissible a few years ago is expected now as the inevitable result of progress. I may, therefore, in this necessarily incomplete review of the subject, properly call attention to a number of schemes recently advanced for the solution of the lighting problem, which, although involving considerable expense and skilled attention, appear to offer collateral advantages.

Car lighting methods can be classified under the following general heads, and will be considered in their order:

1st. Candles.
2d. Vegetable oils.
3d. Mineral or petroleum oils.
4th. Ordinary coal gas.
5th. Carburetted coal gas.
6th. "Rich" or oil gas.
7th. Carburetted air.
8th. Electric.

I. GENERAL DESCRIPTION OF METHODS.

First Method, Candles.—The use of candles for car lighting, quite general fifteen years ago, may be said to be extinct in this country. Abroad, they appear to be still employed to a considerable extent, as in 1887 the German State Railways report 2,420 passenger cars, or 14 per cent. of the total number, using candle-light as their only illuminant. Although I have no figures on other foreign railways, it is fair to presume that a large number of cars in the aggregate are still provided with this primitive mode of light-

*Read before the Western Railway Club, February Meeting, 1891.

ing. The short distances, conservative management, little attention paid to small personal comforts of passengers, and the peculiar compartment construction of cars, probably explain their adherence to this practice.

Second Method, Vegetable Oils.—The use of these oils is, as far as I know, confined wholly to foreign roads. Rape-seed oil is more commonly used than any other, although colza, or oil expressed from a variety of cabbage, is also largely employed. The oils may be burnt in any of the common form of lamps using wicks, in the same manner as our heavy mineral or lard oil. Their use is doubtless a question of availability; foreign roads have been driven to them on account of the scarcity of refined petroleum, being dependent almost wholly upon America for their supply of this oil. The extensive deposits of petroleum in the Black Sea district of Russia furnish little illuminating oil, and that of inferior quality.

Third Method, Petroleum.—These oils are working their way in slowly for car lighting abroad, and may be said to be *the* illuminant in American railway service, the other methods of lighting cutting as yet but an insignificant figure in the sum total. They are obtained by what is called "fractional distillation" of crude petroleum.

The grade of oil used until within the past ten years for car illumination would correspond to the low fire-test oil now used for household purposes, gravity about 50 degrees, firing at 150° Fahr., and giving off inflammable vapor at 110 degrees. The unsafe quality of this oil for the purpose was conceded and the invention of improved processes of oil refining and improved burners made possible the use of a heavy high-test oil, so that it is improbable that any of the light oil is in use at the present day. This heavy oil, called "Mineral Seal," ranges from 36 to 40 in gravity and has a fire-test of 300 degrees; no inflammable vapor being given off below 230 degrees.

Fourth Method, Ordinary Coal Gas.—Abroad the first attempt to use ordinary coal gas for coach illumination was made in England on the London Metropolitan (underground) Railway, by storing it in weighted rubber bags placed on the roofs of cars; the obvious objections to this clumsy plan led to its early abandonment. In this country the only road to adopt, extensively, compressed coal gas was the Pennsylvania, it being until the present time their standard method for all main line cars. The carburetted air plan, described later, has now been, I believe, substituted.

Fifth Method, Carburetted Coal Gas.—Various attempts have been made to overcome the objections to coal gas in the direction of improving its light-giving power and consequently reducing the stored bulk; one method was by "carburetting" the gas before compression. This system is used on the Belgian State railways and in sleeping cars on other European railways, but not, as far as I am aware, in this country. It consists in enriching the gas by passing it through vessels containing gasoline or naphthaline. The volatile oils taken up increase its efficiency of illumination by about 100 per cent.

Sixth Method, "Rich" or Oil Gas.—The lighting of railway cars by means of compressed gas obtained from distillation of petroleum has been in use abroad for many years, notably on the Belgian and German State railways. In 1887, official statistics give for Germany 11,938 cars lighted by gas (Pintsch system) out of a total of 19,663 cars, while to-day, I am informed by the company introducing the method in this country, their European installations foot up to the large total of 36,000 cars equipped. In America this system of lighting, as represented by the "Pintsch," is making rapid headway, nearly 2,000 cars being fitted with it to date. Its principle can best be described by referring to the

Pintsch System.

This is by far the most prominent attempt to devise an economical and practical gas-lighting system I have examined. Its primary object was to reduce the bulk of stored gas necessary to produce an adequate illumination for a considerable length of time. The directions in which improvement in this respect was to be looked for, were obviously in the quality of the gas, the method of burning it, or both.

The Pintsch system has largely confined its attention to more efficient gas, which, it is claimed, is supplied by the use of a rich permanent "oil" gas. Ordinary city or coal gas, when burnt at pressure of the street mains, one to one and one-half ounces may be taken to give an illumination of, at the most, four candles per cubic foot. Oil gas at the same pressure will, it is claimed, give from four to six times as much, say, sixteen candles per cubic foot. But one property of gas, which vitally affects the problem, is the loss of light-giving power upon compression and storage. This is true of all gas, and is due to the deposition of the rich oily hydrocarbons, but it is not true to the same extent for oil and coal gas,

the difference being materially in favor of oil gas. Reliable tests for this loss of light by compression have given the result that coal gas loses 50 per cent. and oil gas 21 per cent. of light-giving power upon compression of 300 lbs. per square inch, and at 225 lbs. per square inch pressure the quantities required for equal illumination would be about as 5 of coal to 1 of oil gas.

The material used for the manufacture of Pintsch gas is crude petroleum. The generation of gas is effected by vaporizing the oil at a high heat in suitably arranged cast iron retorts, the process of manufacture being, on a small scale, essentially that followed for city gas. From the storage tank, pipes and rubber hose connections lead to convenient places for filling the car tanks. A plant capable of making sufficient gas for 500 cars is contained in a one story building, 26 ft. x 38 ft.

The outfit on the cars consists of one or two cylinders for holding the compressed gas, a pressure regulator and a system of piping to the lamps. These are of special design, each having from four to six flames arranged beneath a porcelain reflector, the whole encased in a glass bell jar; ventilation is suitably provided for and a very steady and shadowless light obtained.

It is obvious that the general adoption of a gas-lighting system would entail the erection of suitable generating works, or other means of supply, at such points that the entire equipment would be reached regularly for recharging with gas. In considering this problem for the St. Paul road, it appeared that its passenger service included 570 cars in active service, out of shops; that practically the entire main line traffic and some on branches could be reached from seven distributing points; and that all of this traffic east of the Mississippi River and some west, is reached from 3 centres, handling 376 cars out of the 466 included in the 7 centres above.

The cost of erecting gas works of varying capacities is as follows:

	Apparatus.	Building.	Total.
To supply 500 cars	$11,000	$4,500	$15,500
" " 200 "	9,500	4,100	13,600
" " 100 "	7,500	3,000	10,500

Therefore, suitable works at the seven distributing centres above mentioned, allowing 500 cars capacity plant at one place, 200 cars plant at two places, and 100 at other points, would cost $84,700 or, for the three main centres, $42,700. Taking the first estimate, each car's proportion of the expense of works would be, on basis of 466 cars handled, $181.75. Figuring on the second, the number of cars handled would be 376, or a charge to each car for stationary equipment of $114.

Mention might be made here that an American system, the "Foster," appeared a few years ago, embodying the same principles and general features as the "Pintsch," and though introduced to some limited extent for a time, I cannot find it now in use.

Seventh Method, Carburetted Air.—The only instances I can find of the use of carburetted air gas abroad were trials made in England some time ago of the so-called "Westinghouse" system, on the London and Brighton and South Western Railways. The system was abandoned, however, on account, as stated, of the danger attending the use of volatile oils and the difficulty of regulating the quality of the gas. In this country the only attempt to attack the problem in a scientific manner is by the

Frost System.

In the Frost and all similar systems the principle is the same, being the property possessed by air of holding a vapor in intimate mixture and suspension, usually the vapor of gasoline. The amount of vapor absorbed depends upon its temperature; thus, at 14 degrees above zero about 6 per cent., and at 68 degrees 27 per cent. will be taken up. This is, however, a mechanical mixture only and not a permanent gas.

The vapor thus formed is capable of being burned similarly with gas, when mixed with air in the proper proportions, giving a highly luminous flame. This principle has been utilized for many years for making gas for household purposes in places where city gas is inaccessible; a simple form of air pump run by a falling weight forcing air under a few ounces pressure through a tank (generally buried below frost in the ground), which contains a barrel or two of liquid gasoline. This tank is divided into many compartments in which absorbent wicking is suspended, dipping into the liquid and drawing up the same by capillary attraction. The "enriched" air produced in this "carburetter" forms the burning gas in the system of house piping.

The difficulties to be overcome in using this agent for safe car lighting are as follows: First, the presence of liquid gasoline. The Frost system overcomes this objection by filling the carburetting vessel almost completely with wicking and by merely saturating this with the gasoline, draining off the superfluous liquid. Second, the effect of variation of temperature in the amount of vapor absorbed by the air current. As above stated, in cold weather only a small percentage is absorbed, too little to produce a good light; and in warm weather too much, producing a rich but smoky light. This is really the serious stumbling block to all schemes of this kind. The Frost system claims to entirely overcome it by placing a small generator or carburetter above the light on the roof of the car, in such a manner that a portion of the heat generated by the burner is transmitted to the carburetter, insuring a uniform temperature at all times.

The system in detail consists of an air storage tank underneath the car, containing sufficient compressed air to supply light for six hours. This compressed air is obtained directly from the train pipe of the air brake and is led through a suitable pressure reducer and a regulator to the carburetters in the roof, one of these being placed over each lamp, and thence, after passing through them, to the lamps underneath. These are now constructed on the "Siemens" or "regenerative" principle, and give a brilliant white light without shadow. The supply of gasoline in the carburetters is sufficient for 43 hours' burning, and then can be recharged by filling from the roof.

Eighth, Electric Method of Lighting.—The latest phase of train lighting may be said to be the electric. In this direction numerous isolated experiments have been made in this country during the past five years, but the subject, as usual, has attracted greater attention abroad than here. The different plans suggested for obtaining electric light are divided as follows:

1. Primary batteries.
2. Secondary batteries or accumulators.
3. Dynamo machine connected to car axle, with or without accumulators as auxiliaries.
4. Dynamo operated by special steam engine, either in a car or on the locomotive, and supplied with steam from locomotive or special boiler on a car; accumulators either used or not, as desired, as equalizers.

5. Electric current supplied to the train by contact with wires along the track.

The first method has been tried in England on several railways, and in France on through trains between Paris and Brussels. No trials have been made of it in this country, as far as I am aware. In all, a special form of primary battery, having very low resistance, great surface, and furnishing a constant current at high pressure, was employed. The result was, and always will be with present known forms of primary batteries, flat failures, on account of the enormous expense of the electrical energy furnished by chemical means. The minor disadvantages connected with secondary batteries, mentioned later, are also present. A good idea of what is being attempted will be had when it is said that in primary batteries chemicals are expended and zinc or other metal burnt, instead of coal under a boiler, to produce energy; at the lowest estimate, the former is forty times as expensive as the latter method.

Second method. In England, the London & Brighton Railway made an extensive trial on a Pullman train of lighting by accumulators alone, placing batteries under each car, and having a sufficient number of charging stations, with boilers, engines and dynamos, to charge duplicate sets of batteries for immediate replacement. This system, after five years' trial, was abandoned for the one to be described later. In this country the Pullman Company gave the method a thorough trial on the P. R. R. "Limited" between New York and Chicago, finally abandoning it for a later one. It was also tried and abandoned on the B. & A. Railway, the C. B. & Q., and possibly in other instances. I understand it is in use on the Canadian Pacific Railway, to a limited extent, on the Burlington, Cedar Rapids & Northern Railway, and on some parlor cars on the Pennsylvania Railroad.

Description of this system may be dismissed briefly by saying that each car carries its own store of batteries in boxes hung underneath, arranged so that they can be readily removed at terminals for recharging by dynamo, or for substitution of fresh cells. The weight of batteries required for a standard coach is, approximately, one ton.

Third method. A favorite scheme for obtaining electricity at a low cost seems to have been to connect the dynamo to a car axle; but the difficulties of obtaining regular motion and current, and providing light when the train stops, have necessitated the em-

ployment of accumulators as regulators and auxiliaries In these plans automatic appliances are provided to cut off the current from the dynamo when the speed of the train falls below a certain rate, and to deliver the current to the batteries in the same direction, no matter which way the train may move. Many foreign railways have tried this plan, the most successful instance being of the "Pullman Limited" on the London, Brighton & South Coast Railway, where the system is still in use. The main difficulty, and one which the International Railway Congress states has not been solved satisfactorily, is the method of transmission of power from the axle of the dynamo. This should offer less difficulty in the case of foreign cars, with their rigid wheel base, than with our bogie construction of truck and, although not a mechanical impossibility, other methods seem to offer a better solution.

The fourth method is the only prominent one in this country, but does not seem to have been a favorite abroad; the "Timmis system," in use on the Midland Railway (England), is the only instance I can find mentioned. Here, the Connecticut River road was probably the first to introduce it, being followed by the Pullman Co., on the P. R. R., A. T. & S. F., the C., M. & St. P., Union Pacific and on other isolated trains. The general idea in all is the same and consists in the use of a dynamo driven by special steam engine, with secondary batteries for reserve. The use of the method without the batteries as auxiliaries has been attempted without much success by the Metropolitan (London underground) Railway, in 1884, and in Germany. Difficulty was experienced in obtaining a light and compact steam engine.

The fifth method is used in a number of places in England and Russia for lighting trains for the time being when passing through tunnels. Small contact wheels on the car run on a third rail or wire conductor along the track, completing the electric circuit through the lamps when needed. The method is obviously only adapted to special uses.

As illustrating the development of the electrical method of train lighting on, without doubt, the largest scale in the world, a brief description of the experience of the St. Paul road will probably suffice. The system first experimented with some two years ago and used for a year on two trains, consisted in having a small engine coupled direct to a dynamo of 100 lights capacity, the plant being in the forward end of the baggage car. Steam for the engine was

obtained through the train heating pipes from the locomotive at 60 lbs. pressure. The electrical mains were run on the roofs of the cars under tin, and branch wires brought into the cars for the lights. Under each car were carried 32 cells of secondary batteries, weighing from 1,500 to 2,000 lbs. The electrical arrangements in the baggage car were of a novel character, and allowed the use of the lights direct from the dynamo, from the batteries, or from both simultaneously. They also permitted charging the batteries while running the lights, without affecting the latter, a highly important feature and a distinct advance upon the old methods of storage battery lighting.

In spite of the quite perfect character of this outfit and great care given its operation, we were quite ready to abandon it. Briefly, its very serious defects were heavy first cost, rapid depreciation of batteries (which I estimated at about 40 per cent. per annum), the multiplicity of detail requiring skilled attention, the poor economy of the special engine, and the wasteful character of the whole arrangement in current.

After about one year's experience with the above the following improvements suggested themselves, and constitute the system in use at present. It was considered feasible to do away with storage batteries entirely, relying upon direct generation of the electric current by a dynamo run by special steam engine. The plant, in fact, was made an exact duplicate of stationary electric lighting plants, which experience has demonstrated can be depended upon for continuous work of long periods of time without failure of any kind. In order to insure reliability without further experimenting with special devices, a standard type of engine and dynamo, to be had on the market, was adopted. The engine was a 15 h. p. Westinghouse automatic, the dynamo a 150 light Edison compound wound, connection from one to the other being made by belting. In summer season, when steam heat is not required for the train, this outfit is placed in the forward end of the baggage car, occupying 12 ft. in the length of the car, but not obstructing passage way through it. Steam is taken direct from the locomotive boiler at 60 lbs. pressure.

In winter, the drain upon the locomotive for steam heat and the light proved a very serious matter upon our heavy trains, and at times the steam supplied was totally inadequate for proper heating, to say nothing of lighting; it was, therefore, determined to use

a special car for the heating and lighting during this season. Space will not permit me here to go fully into the experiments instituted to prove the economy of this departure. Suffice it to say that we proved that at least 12 per cent. of the steaming capacity of the locomotive was required for heating and lighting a train of ten cars, in weather above zero degrees, while to haul the extra car we estimated not more than 6 per cent. additional was required. Furthermore, the drain upon the locomotive for lighting and heating is a dead loss of so much steam, adding nothing to the capacity of the furnace to burn more fuel, while the extra power developed in the engine cylinders produced further means for urging the fire. Quite a complete description of this special car, or "Light and Heat Tender," as we call it, will be found in the *Railroad Gazette* of June 13, 1890.

It contains a locomotive type of boiler of special design, coal bunkers with sufficient fuel capacity for 500 miles run, tank containing three hours' water supply, engine, dynamo and the various fittings necessary for regulating the supply of heat and light to the train. The whole is under the charge of one attendant, who fires the boiler, runs the engine for furnishing the light, has charge of the heat supply and the regulators for controlling the same, in fact, is wholly responsible for maintaining both these functions in first-class condition.

The electrical equipment in active service on the St. Paul road comprises the following:

CLASS OF CAR.	No. in Service.	No. Lamps Per Car.	Total Lamps.
Baggage	8	6	48
Mail	5	10	50
Mail and Express	4	9	36
First Class Coach	15	12	180
Chair	3	13	39
Parlor	5	18	90
Dining	5	19	95
Sleeping	17	34	578
Light and Heat Tenders	2	6	12
Total	64		1128

Four through trains are lighted each night, two between Chicago and St. Paul and Minneapolis, and two between Chicago

and Council Bluffs and Omaha. On account of the much heavier service on the Chicago-Minneapolis run, the tender cars are used there only, the Council Bluffs run having light supplied from the baggage car outfit.

II. As to the Amount of Light Required.

Opinions will doubtless differ upon this important head; from considerable personal observation and, I may say, trying (to the eyes), experience upon the representative systems of the country, I offer the following as requisites for satisfactory car lighting:

1st requisite—The head-linings in cars should be light in color and warm in tone; the surface should not be of such a high polish as to reflect light locally in a manner unpleasant to the eyes. The numberless mirrors often added for decorative effect are generally a nuisance, making impossible the

2d requisite, which is to set the lamps in such a position that passengers may readily screen their eyes from the direct view of the flames of light. This condition demands that lamps be placed high.

3d requisite—Good general illumination demands rather a large number of comparatively feeble centres of light than intense concentration in a few lamps.

4th requisite—Economy of light demands sufficient general illumination and brilliant local lighting in positions where the light is to be used for continuous application, as in reading. This condition is difficult to fulfill practically without infringing the second, except in the electric or non-combustion lighting system. An attempt, and we think a successful one, to supply this requisite may be found in the sleeping cars of the St. Paul road where additional lights have been placed in the berths in such a manner that while they are in a position close to the object to be illuminated, they are also perfectly under the control of the passenger, the rays of light being shielded from his direct vision and that of his neighbors.

It may be conceded that application of all of the above principles is impossible, where economy of equipment and service is necessary, and that some of them are, in a measure, contradictory. I am personally convinced that reading at night in a moving car, under any system of lighting, except, perhaps the one last named, is a fruitful source of impairment of the eyesight. Artificial illu-

mination may be brilliant compared to darkness, but it is at best dimness compared to daylight.

Best modern practice (to which, however, I cannot agree for the above reasons), seems to establish the following: for 50 ft. passenger cars, satisfactory illumination, 150 candles of light in the body, for brilliant illumination, 200 candles. For sleeping cars, in the forty feet of main body, satisfactory illumination, 200 candles, brilliant, 240 candles. All the foregoing in overhead sources of light. To fulfill the third requisite, I recommend that, in electric systems, the light be uniformly distributed from equally spaced foci, each having a maximum intensity of sixteen candles and that in other system, no single focus shall have a greater intensity than 30 candles; that, in case of oil lamps where convenience and first cost so demand, these foci be equally spaced in groups of two; that in other combustion systems each focus be single and equally spaced.

III. Question of Safety.

This is a highly important one and can hardly be disposed of in the few words I am able to give it. It comprehends two general phases, safety to passengers and safety to rolling stock; these, not only under running conditions, but in case of accident.

Danger of fire may arise in many ways: contact of flame with wood-work or drapery, overheating of fixtures, communication of fire to the lighting fluid and consequent destruction of lamp, explosion, presence of liquid fuel adding to fire already started, and others.

The first system which is of consequence for discussion is oil lighting. The popular opinion, fostered by ill-informed persons and others, is that "the deadly oil-lamp must go" with the "deadly coal stove." I believe the dangerous character of this method of car lighting to be wholly a delusion. As before explained, in past years low fire-test oil was commonly employed for car lamps, but to-day the oil is of a very different character. The old oil was undoubtedly highly dangerous, it being possible from improper attention to have it at the temperature of vaporization in the lamp pot; thus a jar, current of air, or defect in the lamp would cause communication of the flame with the accumulated vapor and explosion would ensue. But the nature of the oil used for car lighting to-day is not popularly understood, many imagining it to be the household

quality of kerosene; it is, in fact, totally different, being a heavy oil of difficult inflammability. It may be heated beyond the temperature of boiling water without giving off vapor and will consequently not ignite in bulk below this point. The flame in the lamp is very sensitive to draught or jar; in fact, it seems impossible for a fire to originate in case of collision from the light, as tearing a lamp from its fastenings would without fail, I believe, extinguish it. Two other sources of danger exist: first, the possibility of flame coming into contact with wood-work or drapery while the lamp is in position; this defect exists in all systems of flame lighting, but would not seem to offer a valid reason for condemning such systems. The other defect, which is peculiar to oil lighting, is that spilling oil on the wood-work or cushions of a car will add to their inflammability and, in presence of *other* fire, fuel to the flames; but this fire has properly no place in a car and, from present prospects, need not longer be counted as a source of danger.

As for the other systems of flame lighting, represented by the gas and carburetted air, the most we can say is that the elements of danger have been reduced to a minimum by careful attention to details. In the Pintsch system, explosion of a gas cylinder by over-pressure or defective material is a possibility, and in such case would probably result in damage to the car sufficient to cause injury to those in the vicinity. But such contingencies, in face of the vastly greater dangers attending the pursuit of the ordinary routine of existence, need not cause much uneasiness. Spontaneous explosion of gases is an impossibility without the mixture of the proper quantity of air and subsequent ignition in a confined space. In case of wreck the tanks of gas would, if disturbed at all, be swept from their fastenings and the contents harmlessly escape. As to the gasoline or "Frost" system, the same remarks would apply in speaking of the explosive character of the lighting fluid. The chief danger of this latter system is, however, in handling the gasoline; this substance is extremely inflammable at ordinary temperature, it being difficulty to prevent its escape from packages in which it is stored. A prominent road using the system states that 18 per cent. of the gasoline evaporates from closed wooden packages when standing two months in the oil house. Under these circumstances its general use at many points on a large system, by necessarily ignorant men, cannot but be looked upon as a grave source of danger to life and property, and one which would require modi-

fication of the stringent oil inspection laws of many states before becoming legal.

As for the electric system, the danger of fire to the car, although remote, is not an impossibility; imperfect wiring, accidental cross contacts, or meddling interference may cause intense local heating and fire to wood-work. Such contingency is made, however, very remote by the system of safety-fuses adopted in the wiring, and even if fire were started as above, its spread will be slow, allowing for passengers to escape.

IV. COST OF THE VARIOUS SYSTEMS OF LIGHTING.

Probably the most interesting question to the railway manager, after the advantages of a certain system of lighting have been set forth, is that of its cost. I have collected these figures from the best attainable sources, and present some interesting conclusions in the table. The manner in which this table has been prepared will require some explanation. The figures are not all expected to be absolutely accurate, but I have endeavored to make them perfectly fair and as exact as my data would permit. For an equal basis for comparison, a standard 50-foot passenger coach was taken; if special cars had been considered, it is possible the figures would have been relatively changed in some instances, on account of the unequal economy of equipment and operation of the various systems on different candle-power bases.

To fulfill the condition of satisfactory illumination, set forth elsewhere, I have endeavored to fix the candle power in the body of a car as near 150 as possible.

Column 6 provides for rather plain but sightly lamps. In column 7, the interest on first cost has been taken uniformly at 5 per cent. per annum; the rate of depreciation varies according to circumstances, as seen below. This depreciation is outside of the minor supplies and repairs, allowed in column 9, and applies for renewal of the entire outfit at the end of a period when repairs are no longer economical. Total running cost, given in column 10, does not include charges of column 7, but is obtained by adding Nos. 8 and 9.

Column 13 gives means for comparing each system on the basis of equal candle power and is obtained by dividing column 10 by No. 5.

Considering the systems in detail: the figures for candle-light in Nos. 8 and 11 were taken from actual experiment in the St.

Paul Road Laboratory. Those for the Colza oil system, were obtained in the same way. The mineral oil methods, given in lines three, four and five, are results of experiments made by ourselves on different styles of lamps and burners. The candle powers were taken at a practicable height of flame in actual service.

COMPARATIVE COST OF CAR LIGHTING SYSTEMS.

Figures Based on Service for One 50-Foot Passenger Coach.

System.	No. of Burners.		Candle Power of Light.			First Cost of Equipment.	Depreciation and 5% Interest on First Cost.	Cost per Car per Hour.			Cost per Candle Power per Hour. Cents.	Hours Burning Without Refilling.	Cost of Equipment per Candle Power.	Price of Oil or Fuel.
	Main Body.	Closet.	Per Burner in Body.	Total in Body.	Entire Car.			Oil. Cents.	Supplies & Attendants. Cts.	Total Running Cents.				
No. 1, Candles...... ...	4	1	1	4	5	$40.00	$4.00	$0.82	....	......	.164	....	$8.00	9½c. per lb.
No. 2, Colza Oil........	12	1	12	144	156	167.00	16.70	2.22	$1.06	$13.28	085	14	1.07	65c. per gal.
No. 3, Mineral Oil. (Moehring burners..............	12	1	12	144	156	167.00	16.70	1.67	1.06	2.73	.018	15	1.07	9⅝c. per gal.
No. 3, Mineral Oil. (Duplex burners)...... ..	12	1	10.5	126	136½	167.00	16.70	1.21	1.06	2.27	.017	18	1.22	9⅝c. per gal.
No. 3, Mineral Oil. (Acme burners).	6	1*	26	156	168	113.00	11.30	1.94	0.57	2.51	.015	13	0.67	9⅝c. per gal.
No. 6, Oil Gas. (Pintsch)	16	1	10	160	170	552.00	64.07	2.05	0.55	2.60	.015	34	3.24	$1 87 per 1,000 cu. feet.
No. 7, Carburetted Air. (Frost)....	4	1	42	168	180	536.00	80.40	3.48	1.12	4.60	.026	43	2.98	15c. per gal.
No. 8, Electric. Storage and direct current...	9	1	16	144	160	863.00	137.47	....	...	13.20	.083	trip	5.40	
No. 8, Electric. C., M. & St. P Ry. "direct"....	9	1	16	144	160	395.40	36 35	.. .	.....	9 83	.061	"	2 47	

* Moehring.

Figures for the Pintsch system are obtained partly from the Safety Car Heating and Lighting Co., of New York, and partly from experience of a prominent road using the system for the greater part of its equipment. Column 6 includes each car's proportion of the cost of gas works, figuring on works at seven centres, as explained in the body of this paper; this amount was

$181.75 per car and would vary considerably according to the individual conditions of a road adopting the system. The car equipment includes two gas tanks; if one only were used, $85.00 may be deducted. In No. 7, depreciation in gas works is taken at 10 per cent., and 5 per cent. on car equipment.

For the Frost system, columns 1, 2 and 6, were obtained from the company introducing it; the others are the results of recent careful experimenting with the system by a railway company who kindly put them at my disposal. Column 7 is figured on 10 per cent. depreciation, which is my personal estimate, but probably does not overstate the practical figure, when we consider the fragile character of the carburetters and their exposed position. Column 8 includes 15 per cent. added to the gasoline required for burning to make up for the loss in storing and transportation. Column 12 is taken from experiments on the road above referred to and was maximum burning time with full carburetters and gasoline of 88 degrees gravity. In practice they found that the gravity of the gasoline was considerably reduced by absorption of the lighter products first and that after a few fillings the heavier oil caused considerable reduction of light after burning a few hours; thus, at the start the candle power was 45, but at the end of 34 hours burning reduced to 26.6, in one experiment.

The electric system given on line 8 is the first one experimented with on the St. Paul road. The high cost given in column 6 is due to the car's proportion of storage battery, engine and dynamo, and $113 for auxiliary lamp lighting. Depreciation in No. 9, is figured at 25 per cent. for engine, 10 per cent. for dynamo, 33⅓ per cent. on batteries, and 5 per cent. on wiring and oil lamps.

Line 9 gives the St. Paul present electric system. Column 6 includes the car's proportion of cost of tender car and equipment, on the basis of its number of lamps, figuring on four of these cars to the 62 cars in service; also $113 for auxiliary oil lighting equipment. In column 7, depreciation on tender car and equipment is figured at 10 per cent. and on wiring and oil lights at 5 per cent. Lamp renewals are figured in No. 10 as part of total running expenses.

In order to show the items entering into the cost of the electric system at present in use on the St. Paul road, I have thought it might be of interest to give the details. I may say right here

that the rather favorable figures obtained arise from exceptionally favorable conditions resulting from excellent distribution of equipment, heavy continuous service and careful attention to details. The results can in no wise be taken as comparable with other systems in miscellaneous service, or the same system under less favorable conditions. The data for one trip during the month of October, 1890, is :

Train of	10 cars.
Running time	11 hrs.
Maximum lamp load	152.
Average lamp load	87.3.
Indicated horse-power hours	85.6
Water per indicated horse-power hour	57.8 lbs.
Water per trip for lighting	4948 lbs.
Evaporation at boiler pressure per lb. of coal	5.7 lbs.
Coal used per trip	868 lbs.
Lamps per indicated horse-power	10.5.
Coal per indicated horse-power hour	10 lbs.
Cost of coal per ton	$2.00.
Cost of coal per horse-power hour	1 cent.
Attendance	$5.25
Lamp renewals (3 at 40 cts.)	1.20
Oil and waste	.40
Miscellaneous supplies and repairs	.80
Coal for light	.87
Coal to haul car	2.00
Total cost per trip	$10.52
Or, per car per hour	9.54 cts.

In the summer season, when the heat tender is not in use, the total cost per car per hour would be reduced by about two cts., or to 7.5 cts. The figure in the table, column 10, was obtained from the above for a *passenger coach* with all lights burning and, of course, differs from the average figure taken under different conditions.

V. RELATIVE ADVANTAGES AND DISADVANTAGES OF THE VARIOUS SYSTEMS.

From what has been said it becomes evident that perfection of comfort to passengers and minimum danger from fire in car lighting systems are attained only at the expense of much elaboration of [illegible]l and sacrifice of simplicity in operation. It would be useless,

therefore, to lay down requirements for a perfect lighting system, and consideration of the subject reduces to weighing one defective system against another. Of those described we have, I believe, but four worthy of careful consideration—viz.: heavy mineral oil in lamps; the Pintsch oil gas; the Frost carburetted-air; the electric.

The points which should lead us to abandon a system in use and in which we have invested large sums are, safety, better light, cheapness, convenience, advertising considerations and, we might add, in view of future possibilities,—compulsion. Taking up the systems in reverse order :—

The Electric may be considered adapted, in the present state of the art, to *special* service only. It fills a number of the requirements for a perfect light, in a manner that no other light approaches; it is cleanly, cool, safe, allows excellent distribution and is, in fact, a luxury which is duly appreciated by the traveling public. Unfortunately, from a railway point of view, it is not such a success ; it is costly, is adapted to special service only, and requires great attention to details. Still, in many instances, it will undoubtedly pay for itself many times over ; and each railway manager must consider for himself whether, under his special conditions, its use is warranted.

The Frost System.—I am bound to consider this system still in the process of development. It has many advantages from an outside point of view ; it is cleanly, the light is good, each car is perfectly independent of others for its supply of light, and it requires no external gas works. On the other hand the first cost is excessive, the light is not cheap for running, its quality is not uniform—due to the effect of varying temperature and quality of gasoline—the apparatus is complicated and, while the system may be considered safe to the car itself, I believe the use of gasoline at various points on a large system very questionable.

The Pintsch System.—This, in spite of some serious defects, I consider the most feasible and promising attempt in the direction of safety car lighting. It is safe—as safe as any flame method of lighting can be—is cleanly and simple, is cheap in maintenance and running. It is, however, very high in first cost and is not universally applicable, on account of dependence upon gas works. But all main line traffic and many important branch lines can generally be provided for by this system at a moderate cost and, under its

rapid extension now taking place, it seems likely that joint gas works can be maintained by different roads at many points, to still further reduce the individual outlay. The introduction of the system has been pushed in this country lately with a high degree of success; but there are two points I cannot understand in the business policy of the company; first, why they stick to an uneconomical form of lamp, and second, why they import from Germany their entire equipment? This last point has rather an important bearing on the question of repairs; unless they have recently changed, the German (Whitworth) system of screw threads was adhered to throughout.

Oil Lighting by Lamps.—Many of the requirements of a satisfactory car lighting system appear to me to be embodied in the present oil system—or might be, with some improvements which are readily attainable. In no system, with the exception of the electric, is it possible to obtain a better or more satisfactory distribution of light, the centres being of moderate intensity; the fuel is safe to handle and may be anywhere obtained without delay; each car is perfectly independent of others; it is cheapest in first cost and maintenance for a given amount of light; it is simple and easily taken care of. On the other hand, it shares with other flame systems the objections of giving out much heat, and the quantity of light is quite irregular and the smell objectionable when not taken care of. The ground of safety appears to be the one generally attacked; I have elsewhere stated my reasons for not believing this objection has much force. In fact, I believe it is a mistake to abandon the system until a thoroughly better one has been devised—respecting which there is at least a doubt. The possible improvements in this system should have more attention from railway officials and others. For instance, the button form of burners, of which the "Acme" is a good example, appears to solve the problem of sufficient light as satisfactorily as has been done in the other flame systems, and these burners should be substituted for the old uneconomical form.

CONCLUSION.

To conclude; the demand from the railways at the present time appears to be principally for *more* light and a *safe* one. If my remarks to-day (and in which I have endeavored to disabuse my .ind of all prejudice) lead to any conclusion it is; first, that the

present oil lighted cars are, or can be made, the best lighted in the country; second, that oil lighting is not, as popularly supposed, unsafe. This being the case, we should at least look over the situation carefully before jumping into an expensive and complicated system for supposed advantages.

Since the question of car heating has become a "burning" one, if you will excuse the pun, state legislators and the public have properly demanded that the railways should experiment in the direction of something safer. This promises to be productive of good results to the public and railways themselves, but it is to be hoped that the popular outcry will not be directed towards the lighting problem leaving what is really a question of convenience to be worked out by those most interested—the railways themselves.

ANNUAL MEETING OF THE ALUMNI ASSOCIATION.

THE annual meeting of the Alumni Association was held in the Hall of the Stevens School on Monday evening, June 15, President A. P. Trautwein presiding. The meeting was called to order at 8.30 P. M., with an attendance of about 75, including several members of the Faculty.

The reading of the minutes of the previous meeting was dispensed with, as they had been published in the INDICATOR.

The treasurer presented his report for the year ending June 15, which was as follows:

TREASURER'S REPORT.

HOBOKEN, N. J., June 15, 1891.

To the Alumni Association of the Stevens Institute of Technology:

Report for the year ending June 15, 1891:

I.—GENERAL FUND.

Receipts.

Balance in Fund June 18, 1890	$514.58	
Dues for 1890–1891	680.00	
Dues in arrears	90.00	
Dues in advance	6.00	
		$1,290.58

Expenditures.

STEVENS INDICATOR. subscriptions	$348.00	
Donation to INDICATOR for cuts	150.00	
Prof. A. Riesenberger, editing INDICATOR	100.00	
C. F. Bloom, printing	7.25	
Midwinter meeting, expenses	73.50	
F. E. Idell, printing, postage, and clerk hire	67.27	
W. H. Bristol, postage and clerk hire	19.89	
		$765.91
Balance in Fund June 15, 1891	524.67	
		$1,290.58
Dues in arrears		314.50

II.—BENEFICIARY FUND.

Receipts.

Balance in Fund June 18, 1890	$417.71	
D. H. Maury, '84, donation	50.00	
Loans repaid	168.09	
Bank Interest	32.21	
		$668.01

Expenditures.

Loans	$ 50.00	
Balance in Fund	618.01	
		$668.01
Amount of outstanding loans	$ 711.82	
Total amount of Fund	1,329.83	

III.—LIBRARY FUND.

Balance in Fund June 18, 1890	$64.75
Balance in Fund June 15, 1891	64.75

IV.—LIBRARY PORTRAIT FUND.

Balance in Fund June 18, 1890	$40.72
" " " " 15, 1891	40.72

V.—THE STEVENS INDICATOR.

Receipts.

From Business Manager	$545.02	
" Alumni Association, for Cuts	150.00	
Alumni Subscriptions	348.00	
		$1,043.02

Expenditures.

Deficit June 18, 1890	$4.52	
Publication of July INDICATOR, 1890	248.13	
" " October " 1890	273.70	
" " January " 1891	242.85	
" " April " 1891	269.39	
American Photo-Engraving Company, Cuts	15.75	
F. Gutekurst, Portrait E. A. Stevens	28.50	
H. F. Raetz, Addressing INDICATOR and Postage	18.90	
L. C. Bayles, Drawings	2.00	
Aug. Bastian, Balance for Binding INDICATOR	2.00	
		$1,106.24
Deficit to Balance June 15, 1891	$63.22	
Outstanding Bills	$91.00	

The Recording Secretary reported on behalf of the Executive Committee that their labors during the year had been chiefly of a routine nature, and that the Committee had acted upon the recommendation of the Managing Editor of the INDICATOR appropriating $50.00 to the magazine.

In answer to a question by the chair as to whether an additional appropriation would be required, the Managing Editor stated that the report of the Treasurer showed a small surplus, if the unpaid bills were credited to the magazine, and that a further appropriation would, therefore, not be needed.

A vote of thanks was, upon motion of G. C. Henning, '76 given to the Managing Editor for the efficient manner in which he was conducting the periodical both financially and editorially.

The resignations of Messrs. C. A. Carr, Edward E. Magovern, '81, W. A. Magee, '88, H. J. Miller, '84, received by the Corresponding Secretary, were read and upon motion accepted.

Communications from Ernest N. Wright, '83, and Edward P. Robbins, '79, were then read and received ; the former called attention to the advisability of sending all notices to alumni in sealed envelopes as letter postage. Upon motion of E. P. Mowton, '86, the Corresponding Secretary was instructed to mail all notices hereafter, as suggested by Mr. Wright.

Wm. Kent, '76, the Alumni Trustee, reported that the subject of a chemical laboratory with a metallurgical attachment has been

under consideration, only informally, however, but as yet the necessary funds for the purpose were not available.

The election of officers for the ensuing year then followed. E. H. Foster, '84, C. R. Collins, '86 and R. M. Dixon, '81, the tellers appointed by the chair, reported the result of the balloting as follows:

OFFICERS FOR 1891.

President—Edward B. Wall, '76.
Vice-President—F. E. Idell, '77.
Recording Secretary—J. M. Rusby, '85.
Treasurer—Wm. H. Bristol, '84.
Directors. { E. B. Renwick, 84.
E. S. Cronise, 81.

E. P. Mowton, '86, reported to the meeting the action taken by his class of donating the sum of $100.00 to the Department of Applied Electricity, to be used in purchasing a Thomson Balance.

President Trautwein then stated that a pressure of professional duties prevented him from preparing an address, as was customary.

The time usually occupied by the address of the President and the reading of the report of the Alumni Trustee, was taken up by President Morton and several members of the Faculty, who made interesting and entertaining remarks.

President Morton called attention to two facts to indicate that the financial condition of the Institute had not been impaired, notwithstanding the reduction in the rate of interest upon a portion of the funds which had been reinvested during the past year. This was due, in the first place, to the fact that the sum of $12,000, the amount of the Vreeland bequest, had been received by the trustees during the past year, and, secondly, to the prosperous condition of the Stevens School. The moneys received from these two sources, he said, caused a feeling of security in regard to the finances which he was pleased to be able to report. He also complimented the alumni upon the excellent records many were making in their profession, and said that their success was exceedingly gratifying to him.

Professors Wood, Krœh, Wall, Denton and Geyer also responded to the chair's invitation to address the meeting.

Professor Denton's remarks were in a very happy vein and were greatly enjoyed.

At the close of the remarks of the members of the Faculty the meeting adjourned.

The members in attendance were as follows:

Alex. C. Humphreys, '81.
P. E. Raqué, '76.
A. P. Trautwein, '76.
C. R. Collins, '86.
A. G. Glasgow, '85.
Robert Dixon, '81.
J. W. Howell, '81.
Jno. Aspinwall, '81.
M. C. Jenkins, '87.
F. C. Fraentzel, '83.
Lewis H. Nash, '77.
Robt. M. Anderson, '87.
R. N. Bayles, '87.
N. Hiller, '90.
Jos. Wetzler, '82.
Prof. Morton.
F. E. Idell, '77.
A. Riesenberger, '76.
Prof. Geyer, '77.
H. P. Jones, '90.
Paul Doty, '88.
H. K. Morrison, '86.
E. A. Wright, '83.
R. S. Kursheedt, '80.
C. L. Gately, '84.
J. E. Denton, '75.
H. Vanatta, '81.
W. S. Chester, '86.
E. H. Foster, '84.
Ira Wortendyke, '89.
Durand Woodman, '80.
Fred'k Gubelman, '89.
P. C. A. Graupner, '89.
Sam'l Smith, '90.
Wm. L. Lyall, '84.
H. E. Peabody, '90.
Paul Spencer, '91.
A. H. Schlesinger, '87.
Albert Spies, '81.
C. J. Field, '86.
Wm. H. Bristol, '84.
Wm. E. Schoenborn, '87.
Wm. J. Beers, '89.
F. E. Jackson, '86.
E. P. Mowton, '86.
Wm. C. Post, '86.
Edwin Tatham, '81.
Julius Calisch, '87.
Geo. G. Plyer, '89.
Geo. B. Muldaur, '89.
Prof. Wall.
Chas. F. Parker, '84.
A. R. Mount, '91.
D. C. Harvey, '90.
A. W. Brainard, '84.
Edwin Burhorn, '85.
H. W. Smith, '91.
Geo. R. Metcalf, '86.
Dr. Sevenoak.
J. F. Firestone, '87.
D. H. Gildersleeve, Jr., '89.
C. G. Atwater, '91.
Chas. W. Thomas, '84.
H. L. Ebsen, '89.
E. L. McBurney, '89.
Prof. Wood.
H. R. Rea, '84.
J. H. Longstreet, '79.
Prof. Krœh.
Gus. C. Henning, '76.
W. S. Ackerman, '91.
Wm. Kent, '76.
J. H. Cuntz, '87.
B. P. Hall, '88.

L. H. Nettleton, '91.	F. B. Stevens, Jr., '90.
J. A. Dixon, '91.	DeWitt Crane, '84.
Jesse A. Davis, '91.	B. F. Hart, Jr., '87.
C. J. Everett, Jr., '90.	Edw. Ducommun, '88.

A. G. Mayer, '89.

COMMENCEMENT WEEK EXERCISES.

COMMENCEMENT week of 1891 opened with the Baccalaureate Sermon, by Rev. Geo. C. Houghton, at Trinity Church, Seventh and Washington Streets, Hoboken, on Sunday, June 14, at 10.45 A. M. A large attendance of the graduating class and their friends had gathered to hear the sermon, which was delivered in the masterly manner which characterized Mr. Houghton's sermons to previous graduating classes.

President and Mrs. Morton received the Faculty, Alumni and Undergraduates on Monday, June 15, from 4 to 7 P. M. The Alumni were present, as usual, in large numbers, to pay their respects to President and Mrs. Morton, and to enjoy their generous hospitality.

BASE-BALL GAME.—The annual base-ball game between the Alumni and the regular college nine was played on the morning of the 15th. The playing was very close throughout the game, and a lively interest was manifested by the large crowd in attendance, to the finish.

The teams were made up as follows:

ALUMNI.	UNDERGRADUATES.
E. A. Wright, '83, c.	T. B. Cumming, c.
Edward Ducommun, '88, p.	O. B. Shalk, p.
H. R. Rea, '84, 1st b.	F. J. Weeks, 1st b.
J. E. Denton, '75, 2d b.	William E. Strong, 2d b.
E. L. McBurney, '89, 3d b.	George B. Fielder, 3d b.
William A. Adriance, '85, r. s. s.	John Paulsen, r. s. s.
W. W. Shippen, l. s. s.	William A. Field, l. s. s.
A. Riesenberger, '76, r. f.	W. P. Mackenzie, r. f.
C. L. Gately, '84, c. f.	A. Shiebler, c. f.
B. F. Hart, '87, l. f.	A. R. Hake, l. f.

The score by innings was as follows:

Alumni............	1	0	3	0	4	0	1	0	0— 9
Undergraduates...	1	0	4	1	0	0	1	0	3—10

Adriance, Hart and Wright led at the bat for the Alumni, and Cumming, Strong and Paulson for the Undergraduates.

Ducommun, p., McBurney, 3d b., and Hart, l. f., played effectively in the field, as did Cumming, c., Shalk, p., and Paulsen., s. s., for the Undergraduates.

CREMATION OF CALCULUS.—The peculiar ceremonies attending the Cremation of Calculus took place on the evening of the 15th of June. A large number of students representing the several classes of the Institute formed in line on the Campus at about 8 o'clock, previous to marching through the principal streets of the city. The grotesque suits worn by many of the students attracted a large crowd of people to the grounds to witness the ceremonies. The programme, as arranged and carried out, consisted of these eight divisions:

1. Assembling of the Students on the Institute Campus.
2. Forming of line.
3. Line of march.
4. Trial of Calculus on the Campus, in the presence of the assembled multitude.
5. Verdict of Jury.
6. The true inwardness of Calculus revealed.
7. Execution of sentence.
8. The Cremation, grand ballet, by troupe, followed by general rejoicing, jollification, and jubilation.

REUNION, CLASS OF '76.—The attendance of several members of the Class of '76 at the Providence meeting of the American Society of Mechanical Engineers, during commencement week, caused the postponement of the reunion to some more convenient time in the fall of the year.

DECENNIAL REUNION, CLASS OF '81.—The Class of '81 held its reunion at Meyer's Hotel, Hoboken, at 10.30 P. M., Monday, June 15th, 1891. There were present: Alex. C. Humphreys, Albert Spies, Frank Dilworth, H. Vanatta, E. Tatham, E. S. Cronise, J. W. Howell, J. Aspinwall and R. M. Dixon. Prof. Denton was present as a guest. The class decided, by vote, to donate a drill-press to the Institute's shops.

QUINQUENNIAL REUNION, CLASS OF '86.—At the triennial reunion in '89, the class decided to hold annual meetings on alumni day of commencement week.

The third annual meeting was held in the parlor of Bush's Hotel, Hoboken, on the 15th inst., at 6.30 P. M.

There were present Messrs. Birdsall, Collins, Cook, Field, Jackson, Morrison, Mowton and Post.

The class instructed a committee to select a Thomson Balance or Galvanometer for the Electrical Department, to be presented as a gift from the class.

C. J. Field received the award of the class cup, which will be of aluminum, gold-lined.

The election of officers followed, resulting in the choice of C. J. Field, President, and C. R. Collins, Secretary and Treasurer. Messrs. Mowton and Collins were the officers for 1890–91. After adjournment the class entertained a few of the Alumni, Messrs. Denton, Humphreys, Riesenberger, Rea, Glasgow, Gately and others being present. The notice of this part of the meeting was not included in circular issued by the Alumni Executive Committee, otherwise the reception would have been even more of a success. After partaking of some light refreshments the class and its guests returned to the Institute for the regular alumni meeting.

TRIENNIAL REUNION, CLASS OF '88.—The Class of '88 held its Triennial Reunion at Martinelli's, Fifth Avenue and 18th St., New York City, on the evening of June 15, 1891. Messrs. Burton P. Hall, William B. Yereance, A. M. Herring, Paul A. Doty, E. Ducommun, F. Uhlenhaut and R. Beyer were present.

The cup, a beautiful silver token, was presented to Alexander Woodward Yereance, the first son born to a member of the class.

Before adjourning it was decided to celebrate the Quinquennial Reunion in 1893.

THE JUNIOR BALL.—The Junior Class held its annual ball at Sherry's, 402 Fifth Avenue, New York City, on Wednesday, June 17, 1891, at 9.30 P. M.

The attendance was larger than on any previous similar occasion, indicating the increasing popularity of the event.

The committee to whose efforts the success of the ball was largely due consisted of:

Geo. H. Miller, Chairman; H. C. Meyer, Jr., F. L. Waefelaer, Jr., A. J. Post, Jr., Louis Wettlaufer, A. W. Patterson, Jr., and W. C. Cuntz.

Favored by the weather, which was remarkably cool immediately after an oppressively warm spell, and with good music furnished by Gieseman's orchestra, the second Junior Ball held at Sherry's was pronounced an unqualified success.

The patronesses of the ball were: Mrs. Henry Morton, Mrs. C. F. Krœh, Mrs. A. R. Leeds, Mrs. T. B. Stillman, Mrs. M. D. Baillière, Mrs. D. L. Braine, Mrs. M. B. Dodd, Mrs. S. B. Elkins, Mrs. G. C. Houghton, Mrs. J. C. Kellogg, Mrs. E. P. C. Lewis, Mrs. E. H. Litchfield, Mrs. Edwin A. Stevens, Mrs. F. H. Macy, Mrs. H. C. Meyer, Mrs. Thomas Miller, Mrs. A. W Patterson, Mrs. A. J. Post, Mrs. R. B. Post, Mrs. C. H. Schaeffer, Mrs. E. A. Stevens, Mrs. W. W. Shippen, Mrs. Adolphus Smedburg, Mrs. Louis Waefelaer and Mrs. F. W. Wettlaufer.

Among those present were Professors Krœh and Jacobus, and the following Alumni and Undergraduates: John M. Rusby, '85; Wm. J. Hamilton, '89; E. M. Frazer, '90; Albert Spies, '81; Paul Doty, '88; J. H. Cuntz, '87; B. F. Hart, '87; J. A. Norcross, A. J. Post, F. Sanborn, Jno. Darby, Wm. A. Field, C. E. Pearce, F. B. DeGress, Frank Holberton, Chas. H. McCullough, Jr., Geo. F. Perkins, F. U. De la Rosa, Paul Spencer, Alex. Dow, T. B. Atkins, H. F. Cuntz, Morgan Craft, Alvan Boody, Wm. B Field, W. B. Everitt and G. Maynard.

GRADUATING EXERCISES, CLASS OF '91.—The commencement exercises of the Class of '91 were held at Jacobs' Theatre, Hoboken, on Thursday, June 18, at 8 P. M. The very creditable manner in which the class speakers acquitted themselves and the interesting address of Mr. Erastus Wiman were specially noteworthy features

of '91's graduating exercises. The Banjo Club was, as usual, liberally applauded for the excellent rendition of several selections of popular music.

After the music by the orchestra the exercises were opened with prayer by Rev. Edward Wall.

President Morton made some introductory remarks, after which the orchestra rendered a selection from "Martha." Mr. Paul Spencer then delivered the salutatory address, which is given herewith.

SALUTATORY ADDRESS.

Ladies and Gentlemen: The members of the Class of '91 welcome you this evening. The presence of those who are dear to us by ties of blood or of friendship is always an inspiration. To-night, as we stand at the completion of our four years of work at Stevens, and gaze with eager and, perhaps, with somewhat anxious eyes into the uncertainties of the future, such an inspiration is doubly dear. We are soon to go forth to test, each for himself, the value of his training and his own worth on the battle-field of the world. As in the olden time the girding on of the sword by loved hands and the "God-speed" from revered lips made strong the heart of the warrior, so, to-night, we gather from your presence here a renewed purpose to do and to win, in the strife to come, a firm resolve to show ourselves worthy of your confidence.

You, our instructors, who have strengthened the arm and the eye for the contest, who have given us the armor we are to wear, and, what is better, have trained the mind for decision and the heart for duty, in the name of the class I thank you. We believe that you have taught us aright; we are confident that the weapon you have placed in our hands is made of true metal and will not fail us, and for '91 I promise you that the clasp of the fingers on the hilt shall be firm and the blows it deals sure. It is a naked weapon you have given us, we can see no scabbard for it, we glory that we cannot sheath it; we realize that we have not enrolled ourselves among the onlookers, but that the band with which we fight is called to the very front, and there where the smoke rolls thickest and the battle grows hottest, we claim our place. And as each sword flashes in air may it be for the advancement of truth and of science, and to the glory of Stevens.

There are events in the lives of all of us that stand out sharp and clear, events the remembrance of which the years as they pass cannot dim. They are those which mark for us the decisive points of our lives. Like milestones, they stand along the way and tell us that another stage of the journey is gone by. Such an event is that of to-night. Our college days are over; the trials, the pleasures, and the joys which have made up our lives for the past four years are at an end; to-morrow begins a new life, with its new interests and its new duties, a life differing entirely from the old in that henceforth we are to be our own masters and our own advisers. We have looked forward to this evening, many of us at times, when college tasks and college discipline have seemed irksome, with eagerness. We have longed for the time when we should be out in the world working along the lines of our own choosing and winning for ourselves the success that each expects, that each has a right to expect. Now that the time has come we begin to realize that there is some truth in the statement that the easiest tasks are those which are set for us. The new life carries with it the responsibility of self-planned action, a responsibility which is largely increased by the years of study and of preparation which we have spent at Stevens. For, upon the educated man in every branch of life, must fall the heaviest part of the world's work. Whether his education be gained in the schools or at the feet of that stern master, experience, the man of intelligence, the man whose mind is drilled to method and to logical processes must carry the burden of responsibility for the world. It is to him that the leadership will fall; it is to him, in times of uncertainty, when old methods fail or new problems arise, that men will look for guidance; it is ever his duty to toil on unceasingly, planning out the pathway that the mighty army of mankind may march on the more easily and with quickened footsteps.

It is as educated men that we go forth to-night, claiming, by the degree which we are to receive, such leadership among the workers amid the mighty forces of Nature.

It is not an easy profession, that which we have chosen. Success in it means hard work, it means unwearying purpose and constant application; but we believe that it stands among the foremost in its benefits to mankind, the one that more than any other distinguishes this nineteenth century of which we boast so proudly.

"Man," says Carlyle, "is a tool-using animal." Weak in himself, the steer of the meadow tosses him aloft like a waste rag

Nevertheless he can use tools, can devise tools. With these the granite mountain melts into light dust before him; he kneads glowing iron as if it were soft paste, seas are his smooth highway, winds and fire are his unwearying steeds. Nowhere do you find him without tools; without tools he is nothing, with tools he is all.

And it is the perfection of machinery, and the ability to make the mighty forces of Nature work for us that has made possible our present high and extended civilization. Contrast the condition of the world but a few hundred years ago with that of to-day. See the ignorance, the poverty, the misery in which the great majority of men were then buried, and tell me if the increased blessings which we now enjoy are not due in great part, directly or indirectly, to the intelligence and ingenuity of the men of the engineering profession.

Was there ignorance then? Yes, and it exists now; but the printing press, scattering its pages to all the winds of the heavens, has made ignorance a crime. Poverty? But every turning spindle, every smoking furnace, every glowing forge is contributing to the wider spread of wealth and to a consequent increasing degree of comfort. Did men in those dark days, gathering themselves in little groups, glare at each other like wild beasts, while every hand twitched to grasp the throat of a neighbor? But to-day the swift steamers which cross our oceans, and the railroads which cover the continent with a very network, are binding the nations of the world together in a community of interests that will soon make war an impossibility, and bring about that brotherhood of man of which we so fondly dream. The throb of the steam engine has become the very pulse of mankind. Let that steady beat but slacken and desolation and despair would follow.

With such a record of achievements in the past, and with a future, the glories of which the boldest of us would hesitate to predict, do you wonder that to-night our hearts beat high with pride and hope? We, too, are to join this noble army of workers; the memories of the past are to be our memories, the hopes for the future are to be fulfilled in some part by our efforts.

Classmates, shall we not realize the importance of the opportunities which lie in our grasp; shall we not gladly accept the responsibilities which they bring, and making our aims high, step forward to win, and to hold the positions of leadership which should be ours? "Going forth to meet the shadowy future without fear and with stout hearts."

Mr. Erastus Wiman then addressed the graduating class upon the subject "Suçcess in Life."

The address was replete with happy statements. He said: "Nine-tenths of our people barely earn enough to supply themselve with food and clothing, a fact that is proven by statistics of the number of persons who are rent payers.

"The way to succeed is to supply a want," and here he gave as an instance the introduction by himself, into this country, of the slot weighing machine. "The desire of people to know their weight was a small want, the supplying of which, I am almost ashamed to say it, netted a handsome return."

He referred to the farmers of this country as the most unhappy portion of our population, and gave as the cause of their present condition the fact that they had, to a large extent, hypothecated their lands, and were obliged to pay a high rate of interest on their loans.

He cautioned the members of the graduating class and young men generally not to hypothecate their future as, he said: "their future is all that many young men have."

He believed that the mortgaging of farms, the bonding of railroads, this vast system of credit upon which the business of the country is being conducted, was accountable for much of the existing feeling of uneasiness and for the present condition of the farmers, who ought to be among the most prosperous of our population. He also referred, in this connection, to the inadequately paid mine labor of Pennsylvania.

The great competition in business and the advanced stage of development of our country make the attainment of success more difficult now than formerly. "Years ago," he said, "war was a business, to-day, however, business is war."

In closing, he advised the class to be ever on the alert to make the most of their opportunities, that success could not be achieved by those who move along listlessly, nor by him who thinks it matters not whether he catches a boat or a train. keeps an engagement or

cultivates an acquaintance. "Above all be careful not to pawn your future."

After the music by the orchestra the Degree of Mechanical Engineer was conferred by President Morton upon forty-four graduates. The following is a list of the graduates and the subjects of their theses:

Wm. S. Ackerman, Benjamin W. Carll,
Rotary Steam Snow-Shovel.—"Leslie Brothers Patents."

C. G. Atwater, Chas. B. Hodges,
Efficiency Test of the New Pulsometer.

A. P. Boller, Jr., H. J. Schumacher,
Determination of Power to Drive Machinery for Turning New London Bridge.

Wm. S. Buvinger,
Review of the Railroad Bridge over Allegheny River at Pittsburgh, Pa.

John Darby, H. W. Smith,
Analytical Study of a Straight Line Engine.

Jesse A. Davis, F. B. De Gress,
Review of the Dover Electric Light Plant.

Francisco U. de la Rosa, Robert A. Hann,
Effect of Moisture on the Insulation of Wire.

J. Alfred Dixon, Henry A. Wolcott,
Test of a Compound Marine Engine with Canfield Piston Valve, on Tug Boat "America."

Alexander Dow, Julius Oelbermann,
Test of the Incandescent Electric Light Plant of the "Navarro" Apartments, New York City.

Louis E. Elson,
On the Construction of Electric Railways.

C. Temple Emmett, Chouteau E. Pearce,
Water Filtration by Mechanical Methods.

Albert W. Erdman, Louis Walker,
Some Mechanical Properties of Vapors, Especially of Steam.

Wm. A. Field, James T. Wallis,
Development of Smoke Box of Locomotives.

Fred Taylor Gause, Arden Post,
Effect of a Perfect Spray Injection on Efficiency of an Air Compressor.

Johan M. L. Hansen, Geo. C. Holberton,
Review of the Brooklyn and Coney Island Electric Railway.

Frederic L. Joubert,
Theoretical Comparison of Thomson and Edison Systems for 1,000 Lights.

Anthony Kennedy, Julian C. Smith, Griswold Knox,
Comparison of Electric Lighting Plant Driven by Water Power or by Steam.

J. HENRY LIENAU,
Electrical Properties of Aluminum.
EDWIN S. LORSCH,
Test of Dynamo and Engine in New York Athletic Club House.
GEORGE L. MANNING,
Determination of Boiling Point of Nitro Benzol.
EDWARD S. WUICHET, CHARLES H. MCCULLOUGH, JR.,
Experimental Determination of the Efficiency of a Pelton Water Wheel.
ALBERT R. MOUNT, LLOYD H. NETTLETON,
Efficiency Tests of Electrical Generators both as Dynamos and Motors.
JOSEPH A. NORCROSS, FRANCIS N. SANBORN,
Efficiency Test of Thomson-Houston Series Machines.
GEORGE S. PERKINS,
Experiments upon Triangular Cast-Iron Beams.
PAUL SPENCER, GEORGE F. SUMMERS,
Test of Electric Plant of the Newark Passenger Railroad.

Music was next rendered by the orchestra, and then Mr. Alexander Dow delivered the Valedictory Address, which was as follows:

VALEDICTORY ADDRESS.

Ladies and Gentlemen: It has been said that the man who first discovered that one and one make two gave us the key of the universe, and that his brother savage, who first extracted iron from its ores, was the father of that long line of engineers who laid the foundations of civilization in the remote past. He placed in the hands of the human race its most powerful weapon—a weapon by which nations are formed, through whose use they attain their growth, and the neglect of which means their national decay.

This is especially an age of iron and of engineering. But it is the mathematician, the physicist, the chemist, and the metallurgist, who, through their combined researches, have given to the engineer the means of making subservient to man all the known forces of Nature. The vast material progress, which, during the last one hundred years, has so eclipsed all that history has previously recorded, is the direct result of the working, side by side, of the scientist and the engineer.

The scientist, by untiring observation and repeated experiment, brings to light unchangeable principles of nature. Guided by a knowledge of these principles the engineer can rear stupendous structures and set in action gigantic workers who know no fatigue,

and whose irresistible energy decides the victories of war and of peaceful commerce.

To those who feel the trend of the time, the literary annals of the distant past are a too tranquil study. There is for them a more potent charm in the human power that compels for mankind the service of the genii of the earth and air. Had the story of the scientific achievement of to-day been told to our fathers when entering their classical colleges, it would have sounded to them like a tale of the Thousand and One Nights. The end of our century is so rich in the development of scientific thought, that, as we are about to knock at the portals of the twentieth century, we doubt if it can startle us with wonders great as those with which we are already so familiar that they no longer occasion surprise. It is true that we have come no nearer to the infinite mystery of nature than the old Persian when, to quell his conceit, he was asked, "Canst thou know the balancing of the clouds?" We must still stand in awe before the impenetrable secret that she forever hides from us; but have we not, through the discoveries of our time, been enabled to chain her lightnings and make them our servants? Only the wildest dreamer could foretell the future progress of science and engincering. Dreams, fantastic as those of Aladdin, have become realities, and man no longer hesitates at the mightiest undertakings.

Over the wide expanse of our country, whose growth has so astonished other and older nations, the march of material progress knows no obstacle The fields of opportunity for the student of technology are ever widening, and it is for men of the present and future generations to occupy them with ability and with honor. In the lines of engineering there can be no dishonesty. Legislators may make bad laws and practice for selfish greed because the result of their work is slow and disaster gradual. But in the case of the engineer "sentence against an evil work" is executed so speedily, the result of shortcomings is so swift and appalling, that the lesson of the necesssity of knowledge and honesty in all detail is constantly enforced.

I need not refer you to the superiority of the school from which we have the honor of graduating; a School of Engineering which, so early in its history, has attained rank among the best of the world's colleges of higher learning; whose name is already spoken with respect in the old world as well as in the new; a name

which will be written in enduring works that will be the pride and honor of our country and our age.

From those among you who are acquainted with the methods of our Alma Mater, we can reasonably expect congratulations to-night, for you appreciate that the way through which our honored masters have led us has not been a path of dalliance and flowers; and you understand the pride we feel in having our names forever associated with the Stevens Institute of Technology.

The crowning event of our college course, which you have so kindly honored by your presence, is to the graduate an event of supreme importance. It is the celebration of victory after a long and serious battle; it is the opening of a longer campaign in a field already occupied by veterans; it is the close of a period filled with the hard study of theories and principles, and the beginning of another period in the school of application and adaptation to all the exigencies of active, practical life.

Should any graduate of Stevens fail to become a useful factor in the world's progress, it will not be for want of serious training.

The Class of '91 will seek to make good the expectations of their friends by earnest endeavor toward the good of their country and the honor of their Alma Mater.

Mr. President, Gentlemen of the Faculty, and Honored Trustees:

In behalf of my class I would express to you our deep appreciation of all your kindness, your patience, and your earnest efforts to cultivate in us that clear insight of scientific truth which so distinguishes you. The memory of your great learning and of your devotion to the interests of science will be to us throughout our lives an inspiration to high endeavor in the fields in which you have aimed to fit us. We trust that you have imparted to us something of that noble purpose that animates you: and that the future may prove that your labors for us have not been in vain. If we have sometimes failed, it is possible that from these failures there has come the beneficent result of a new determination, and an increased capacity for work.

To you, Mr. President, whose lofty purpose, whose self-sacrifice, and whose ability have placed our college in the high position that it holds to-day, we offer our double thanks, that you have made possible for us, and those who follow us, so thorough a course of study. Accept our congratulations for what you have personally

accomplished, and our best wishes that in your own lifetime your highest ideals may be realized.

In bidding you and your learned colleagues farewell, we can ask no higher future for ourselves than that we shall never by act or negligence mar the fair escutcheon which you permit us to bear.

Be assured that whatever fortune betide, our pleasantest recollections will be those of our days of study under your stern but kind guidance here at Stevens.

Classmen: Companions of four long years of ardent toil and pleasant intercourse, we have shared alike some hours of doubt and discouragement, and many moments of satisfaction in the achievement of our tasks. We have known some weariness at times, but we have had enough of conquering energy to bring us to the proud culmination of our efforts, the exercises of this happy day. It is a day in which we rejoice not only each for himself, but each for all his class. The success of a classmate is as dear to a student as his own; and that fraternal interest will live, when we no longer meet in the halls of the college. We have been bonded together by a friendship whose cultivation extends over the brightest period that life affords. We have passed side by side from boyhood into manhood, with surroundings, with interests and with aspirations all in common. Should any one of us during life's voyage drift near dangerous shoals, a '91 pilot would always prove a willing and a friendly guide; and if in future the world should point to one renowned, we should glory in hearing that he was a graduate of Stevens, but how much greater would be our pride and without a pang of jealousy, if we could say, Yes, he was in the class of '91. We have not made for ourselves a record of physical prowess like the men of many literary colleges, but the years of rigorous training and testing of mental muscle ought to leave us prepared to push off our boats upon the sea of practical life with confidence and courage.

We have been engaged for four years in the pursuit of truth, whose unalterable standards have constantly been before us, and our steps have been guided by her greatest exponents. There are no qualities of mind more noble or more earnestly to be desired than those engendered by a love of truth. Surely we have gained somewhat of this. Honesty and accuracy we must have learned, and these must be the insignia of the profession whose gates are to-night thrown open to us.

We are about to enter as workers in that great fabric of engineering that will forever stand a monument of human skill, whose every stone is set in perpetual truth and can never be dislodged Whose every part is built according to the edicts of Divine Wisdom and can only crumble when Nature's laws are no longer steadfast.

The opportunity has been allotted to us of perhaps adding our contribution to this proud, unfinished structure. Our life's duty here is the examination of our Master's work, that we may build in harmony with our predecessors. The responsibilities that they have so nobly borne, we may be called upon to assume when they lay down their tools, and our duty to them can only be fulfilled by making ourselves worthy in their eyes to continue their work. Once so esteemed, let us never be found incompetent.

We have learned to handle a little the tools that they have given us, with which we may accomplish what we choose. Let us see that they never grow rusty, and let us look forward to some worthy achievement.

As we go forth to-day from college life, it is not as we entered, hand-in-hand, with ranks unbroken, bound for the same labors and the same end. We miss with sadness some of the most talented of our number, who, in the midst of their work, were called away by death. For us who remain, our paths must henceforth diverge. Each man will take his separate road, and here at the cross-roads we assemble to shake hands, and to say to each other, God Speed you and Farewell.

When in future we look back, and college days and our commencement recede farther and farther from us, the picture will, no doubt, wear a tenderer, a more alluring aspect. We shall think of the friends of the past four years with a peculiar affection, with which the friendships of after life can scarcely be compared. We have stood shoulder to shoulder in attacking the hard problems set before us, and have rejoiced together in vanquishing difficulties. In future we must work without the stimulant of each other's efforts, but from our distant positions there will always go back and forth, from classmate to classmate, the heartiest good wishes, and, in hours of need, kind words of encouragement.

And so we part, and in the name of all the class, it is my honored, though sad office, to bid you each an affectionate Farewell.

After the banjo club rendered several selections the exercises closed, Benediction being pronounced by Rev. G. C. Houghton, M. A.

The following are the names of the members of the committees appointed by the Graduating Class.

Class Committee.—F. B. De Gress, Wm. A. Field, Julian C. Smith, Chas. H. McCullough, Jr., A. P. Boller, Jr., J. Alfred Dixon.

Reception Committee.—Henry C. Meyer, N. S. Hill, Andrew J. Post, Jr., Kingsley L. Martin, Willis B. Everitt.

Receptions were tendered to the Graduating Class by the following fraternities represented at the Institute:

Mu Chapter, Chi Phi Fraternity, Monday, June 15, 4 to 7 P. M.

XI. Chapter, Chi Psi Fraternity, Tuesday, June 16, 4 to 7 P. M.

Rho Chapter, Delta Tau Delta Fraternity, Wednesday, June 17, 4 to 7 P. M.

ATHLETICS.

Now that the season of 1890–91 is over, and the results are before us, it may be worth while to sum them up and, to try and see where our weak points have been, in order that they may be strengthened next year. The lacrosse season has been very successful, and Stevens has reason to be proud of the good showing made by her team. In track athletics we have done well, when the poor grounds and the inclemency of the day of the games are considered. In base-ball lack of practice has made itself felt in several severe defeats. The redeeming feature was the two defeats inflicted upon our old rivals Rutgers. Finally, in foot-ball we made no record at all, either good or bad.

In connection with our failures, the phrase "Stevens Luck" has been often heard, as if luck had anything to do with our success. The term is only an easy way of getting around the unpleasant fact that Stevens teams too often show the lack of hard work and daily practice, and that the college fails to give them the proper interest. "Stevens Indifference" would express the truth more forcibly. It is time that the college at large should realize that no success comes without hard and persevering preliminary work. That if a team, composed of such men as we have in the Institute, practices regularly and conscientiously every day they must be rewarded by a reasonable amount of success; but that, on the other hand, if daily practice is neglected, interest allowed to wane, and the team only brought together a few days before a game, defeat will follow in nine cases out of ten. We need go no further than the record of the lacrosse team to find an example of success, following careful preparation. "Practice makes Perfect." In the fall we shall have to face the question—Shall Stevens re-enter the foot-ball league? There probably is not a man in the college who is not in favor of this step. Assuredly out of the fifty athletes who

trained for the class teams last fall, eleven good men can be found to carry the red and gray to the front. Then also the college will have to awaken to the fact that the resources of the Athletic Association have been seriously crippled by the loss of the rental from the St. George Cricket Club, and that then, more than ever, it will need the moral and financial support of every student. It seems incredible that where the dues are so small, and the privileges secured so valuable, that less than one-third of the students are members of the Association, but such, to our shame, is the fact. It behooves each of the 150 men who have not joined, to remember that without their aid next fall the Association cannot act, and therefore, whether Stevens is represented in the field or not, will depend largely upon them.

The thanks of the Institute are due to Captain J. C. Smith and Mr. Giroux for the able manner in which they handled the lacrosse team. It is to be hoped that the practice of providing a coach for the team will be kept up for the future, and that we may have the good fortune to secure Mr. Giroux's services next season.

LACROSSE.—The lacrosse season of '90–'91 has just come to a most successful close. While we have not won all that we may have hoped, we have won all that we could expect, and the record of her team is one of which Stevens may well be proud. It was hardly to be expected that we should defeat Lehigh or Johns Hopkins, and, therefore, we are in the last place in the intercollegiate league. The games with these colleges were, however, very stubbornly contested, and the hard struggle Lehigh's fine team had to win shows how strong our team really was. Indeed, the veteran player, Mr. Flannery, speaking after the game with the New York A. C., said it was the strongest team that Stevens had put in the field for several years, and that if they played together another season they would be a crack team. Happily, with only two exceptions, all of the team will be in college next year. Our prospects, therefore, are very flattering, and if the team keeps up the same persevering and diligent practice as distinguished it this year under the management of Captain Smith, we may, perhaps, have the satisfaction of squaring matters with our old friends the Hopkinites.

In the Metropolitan League we are tied for first place with New York A. C., and College City, of N. Y. A most anomalous condition of affairs, and one for which New York A. C. is solely responsible, Had it not been for her overweening confidence, which led her to believe that she could defeat C. C. N. Y. with any kind of a team, the case would have stood: First, N. Y. A. C.; second, Stevens; third, C. C. N. Y.

The team as before stated, was one of the best that Stevens has ever put on the field, rivalling the crack team of '88. That the students were quick to appreciate this was shown by the excellent scrub for the varsity practice, and the large and enthusiastic attendance at the games.

The players, with their positions, were as follows: Coyne, '94, goal; H. Cuntz, '93, point; Martin, '92, coverpoint; Maxfield, '94, first defense; Griswold, '93, second defense; Atwater, '91, third defense; J. C. Smith, '91, Cap-

tain, centre; Kellogg, '94, third attack; Howell, '94, second attack; H. Post, '92, first attack; W. C. Cuntz, '92, outside home; and C. MacCord, '94, inside home.

The first game of any importance was the practice game, with the Staten Islanders, at Staten Island, which resulted in their favor by a score of 3 to 2. The Staten Islanders are one of the strongest teams in the country and Stevens did well in keeping the score so even. The next game was the championship game with the New York A. C., which went to that club by a score of 3 to 0. This was a disappointment, as we had hopes of winning. Loose playing by the defence and inability to handle the ball by the attack allowed N. Y. A. C. to throw three goals during the first half. In the second, the defence braced up and played a remarkably strong game, preventing further scoring. Hodges, '91, goal, broke his ankle during the game and Hake, '92, filled his place.

Next came the championship game with Lehigh. This proved a very agreeable surprise. Lehigh came to Hoboken prepared to sweep all before her, but after an hour's play was very glad to go away with the score 5 to 4 in her favor. The first goal was thrown for Lehigh by Gjertsen in seven minutes, and the second, four minutes after, by the same player. Post then dribbled the ball through them for fifty yards, passing to MacCord, who made a fine throw, scoring the first goal for Stevens. Five minutes later W. Cuntz again scored for Stevens, tying the score. At this point the superior training of the Lehigh men began to tell, and Gjertsen soon shot two more goals, despite the desperate efforts of our defence. Hope soon revived, however, when Post, after a good run, slipped the ball through Lehigh's posts. With the score 4 to 3 in their favor Lehigh scored their last and winning point, Ferridey kicking the ball through in a scrimmage. One minute before time Post threw the last goal for Stevens on a quick pass from MacCord. The playing of the whole team was fine and left scarcely anything to be asked for, but the play of W. Cuntz, Post, and MacCord, on the attack, deserves especial mention.

The last game of the season was played in Baltimore, against Johns Hopkins. The team was much weakened by the loss of W. Cuntz, on the attack, and H. Cuntz, on the defence. The grounds, too, were wet and in a poor condition, rendering it almost impossible for the players to keep their feet. The only feature of the game on Stevens part was the magnificent playing of Coyne at goal, his skill saving the team from a much worse defeat.

Johns Hopkins shot goals at regular intervals during the game until they had obtained seven. The only goal for Stevens was thrown by MacCord at the end of the game.

Following is the summary of games:

Intercollegiate Series.

May 9, Stevens *vs.* Lehigh, at Hoboken; score, 4–5.
" 16, Johns Hopkins *vs.* Lehigh, at Baltimore; score, 5–2.
" 23, Stevens *vs.* Johns Hopkins, at Baltimore; score, 1–7.

Metropolitan Series.

April 25,	Stevens *vs.*	Corinthian A. C., at Staten Island; score, 5–3.
May 2,	" "	New York A. C., at Hoboken; score, 0–3.
" 5,	" "	College, City of N. Y.; forfeited to Stevens.
" 14,	" "	Brooklyn; forfeited to Stevens.
" 19,	" "	Jersey City Lacrosse Club, at Hoboken; score, 6–0.

Practice Games.

Feb. 25,	Stevens' *vs.*	New York A. C., at New York; score, 1–2.
April 14,	" "	College, City of N. Y., at Hoboken; score, 6–0.
" 17,	" "	Jersey City L. C., at Hoboken; score, 3–0.
" 18,	" "	Staten Island A. C., at Staten Island; score, 2–3.
May	" "	New York A. C., at New York; score, 5–5.

Total number of points scored: By Stevens, 33; by opponents, 28.

Base-ball.—The base-ball enthusiasts at Stevens have had a hard time of it this spring. The team started out well, defeating Rutgers and the strong Calumets of New York, but insufficient practice, carelessness, lack of interest, and unhappy faculty of making errors, rendered them easy victims to the stronger clubs of Cornell and Fordham.

It seems a pity that, with such good players as there now are in the college, Stevens cannot put a team in the field capable of playing a reasonably long schedule, and of winning their share of the games. As we suggested in our last issue, the probable reason why lacrosse is so much more popular at the Institute than base-ball, is that we belong to a lacrosse league, to two in fact, while the ball players are confined to the meagre opportunities that neighboring colleges can give them at odd moments.

The team was made up as follows: Cummings, catcher; Schalk, pitcher; Weeks, 1st base; Strong, 2d base; Fielder, 3d base; Darby, left field and captain; Shiebler, center field; MacKenzie, right field.

Below is a summary of games played:

April 18,	Stevens *vs.*	Calumet, at Hoboken; score, 24–6.
" 29,	" "	Rutgers, at Hoboken; score, 10–7.
May 1,	" "	Cornell, at Ithaca; score, 0–13.
" 2,	" "	" " " 0–25.
" 5,	" "	Fordham College, at Fordham; score, 0–19.
June 3,	" "	Rutgers, at Hoboken; score, 15–10.

We would again urge upon the executive board of the athletic association the necessity of taking prompt steps to secure admission into some collegiate league, if they are desirous of conserving the interest in base-ball. As a suggestion, why not form a league of the colleges in the vicinity of New York. Fordham, Columbia, New York University, Stevens, Rutgers, and perhaps one or two others would make a good league, and there would be no heavy expenses incurred in long trips to distant colleges.

'93-'94 Lacrosse Game.—The annual Freshmen-Sophomore lacrosse game was played May 20. Rain fell both before and during the game, and the wet and slippery grounds were the cause of many awkward falls. '93's team was much stronger than had been expected, and the Freshmen won, after an exciting game, by a score of only 5 to 2. For '93, Mackenzie

in goal, and H. Cuntz, Riege, and MacDonald did the best work, while Coyne, Maxfield, Kellogg, Howell and Maynard carried off the honors for '94.

Spring Games.—The Annual Spring Games of the Athletic Association came off successfully on Tuesday, May 26. The weather was inclement, as usual, and record-breaking was rendered almost impossible by a heavy shower which occurred during the early part of the games. The attendance was large and enthusiastic, and remained so despite the rain.

Coleman, '94, carried off the honors, winning 22 points for his class, and making a new record for the standing broad jump—10 feet 1¾ inches. He also established a record for throwing the 16-pound hammer—65 feet 11 inches. Post and W. C. Cuntz tied the score in the three-legged race, and '93's relay team lowered the time for that race from 4 minutes 7 seconds to 3 minutes 59⅗ seconds.

The upper classes had but few entries, and the day was made doubly exciting by the intense rivalry between the Freshmen and Sophomores. The latter proved especially strong in the runs, but the Freshmen succeeded in taking most of the other events, and won the handsome banner, offered by "The Stevens Life," by 14 points. The intercollegiate system of scoring—five points for the winner, two for second, and one for third place—was used.

The officers for the day were: Committee—K. L. Martin, W. E. Strong, A. E. Merkel. Referee—Dr. F. L. Sevenoak. Starter—J. E. Doldt, O. A. C. Clerk of the Course—A. E. Merkel. Field Judges—C. H. McCullough, E. Wuichet. Track Judges—J. H. Cuntz, C. G. Atwater, N. S. Hill. Timers—Dr. T. N. Gray and Mr. Le Roy C. Fairchild.

The following is a summary of the games:

Event.	First.	Second.	Third.	Time or Distance.		Best Previous Record.	
				M.	S.	M.	S.
100 yards dash	H. Cuntz, '93	Klumpp, '94	Simpson, '93	10⅖			10⅕
220 " "	Simpson, '93	H. Cuntz '93	Klumpp, '94	25			24⅕
440 " "	Simpson, '93	H. Cuntz, '93	Maynard, '94	59⅗			53⅕
Half mile run	Borland, '94	L. C. Bayles, '93	Kollstede, '94	2	22⅗	2	14
Mile run	Borland, '94	L. C. Bayles, '93	...	5	40⅘	5	25
Class relay race	Simpson, Mackenzie, Merritt, H. Cuntz, '94	Maynard, Shoemaker, Klumpp, MacCord, '94	Martin, Post, W. C. Cuntz, Patterson, '92	3	59⅗	4	7
Three-legged race	W. C. Cuntz, Post, '92	H. Cuntz, Craft, '93	...		14		14
				Ft.	In.	Ft.	In.
Throwing lacrosse ball	MacCord, '94	H. Cuntz, '93	Maxfield, '94	346	10½	347	8
Throwing base-ball	Strong, '92	MacCord, '94	Klumpp, '94	297		355	9½
Throwing 16 pound hammer	Coleman, '94	Whitehead, '94	Schumacher, '93	65	11	...	
Putting 16-lb. shot	Lord, '93	Coleman, '94	L. C. Bayles, '93	30	6	36	9
Running high jump	Coleman, '94	Maynard, '94, Craft, '93	tied for place	5	2¾	5	3¾
Running broad "	Coleman, '94	Kollstede, '94	Craft, '93	18	3	20	5½
Standing broad "	Coleman, '94	A. Post, '91	Craft, '93	10	1¾	10	½

Points scored, '91—2. '92—10. '93—39½. '94—53½.

TREASURER'S REPORT.

STEVENS INSTITUTE ATHLETIC ASS'N IN ACCOUNT WITH HERMANN F. CUNTZ, TREAS.

Dr.

1891.			
		Balance received from former Treasurer	$381.32
Jan.	13.	To Hill, '92............	3.00
"	13.	" St. George's Cricket Club (rent on account for '90)..........	100.00
April	7.	" Corbin, '94	5.00
"	8.	" Verley, '94........	3.00
"	9.	" Bristol, '93.............	5.00
"	10.	" Maxfield, '94....	2.00
"	10.	" Kellogg, '94..	5.00
"	10.	" Gallagher, '94...... ...	5.00
"	13.	" Ellsworth, '94....	2.00
"	13.	" Kenyon, '94	5.00
"	13.	" Shiebler, '92...	5.00
"	14.	" Hupfel, '93.......... ...	5.00
"	14.	" I. C. A. A. A. A. (Dividend '90).............	156.66
"	16.	" Whitehead, '94..	5.00
"	16.	" Maxfield, '94..	3.00
"	16.	" Angell, '94............	5.00
"	17.	" Barnum, '95	5.00
"	19.	" McGahie, '92....	3.00
"	19.	" Gate receipts (Calumets).....	2.30
"	22.	" Colton, '94..	5.00
"	22.	" Paulding, 95...........	5.00
"	22.	" Anderson, '94.........	5.00
"	29.	" Ruprecht, '94.	5 00
"	29.	" Gate receipts (Rutgers)	8.25
May	2.	" Lowenherz, '92........	3.00
"	2.	" Gate receipts (lacrosse)	6.25
"	4.	" Cornell guarantee, less expenses	112 50
"	4.	" McGowan, '94...	5.00
"	4.	" Maynard, '94	3.00
"	6.	" Fordham guarantee, less expenses...	2.15
"	9.	" Gate receipts (lacrosse, Lehigh)...	9.70
"	20.	" Gate receipts (Spring Games, less expenses)	7 04
June	2.	" Gate receipts (Rutgers)	2.60
		" Locker Rental to date.	10.55
			$896.32

Cr.

1891.			
Jan.	21.	By '89 F. B. Team photo..	$ 1.50
Feb.	11.	" Lacrosse Team........	10.00
"	16.	" Baseball Team........	10.00
March	7.	" '89 B. B. Team photo..	1.50
"	7.	" Letter Box at Institute	.25
"	21.	" Lacrosse Team (suits)	15 00
"	21.	" Dues to I. C. Lacrosse League	5.00
April	4.	" Bats and balls for team...	12.50
"	4.	" Frame for team photos	6.00
"	6.	" Baseball Team (suits)	105.25
"	9.	" Lacrosse Team (suits)	50.00
"	9.	" Baseball Team	10.00
"	10.	" Boehm Bros., stationery	6.50
"	15.	" Shoes for B. B. Team..	7.00
"	17.	" Baseball Team..	10.00
"	24.	" Mits for B. B. Team...	3.00
"	24.	" Boehm Bros , posters.	2.50
"	24.	" George W. Vinten, plumbing......... .	3.75
"	24.	" Lacrosse Team........	20.00
"	29.	" Baseball Team (bats).	2 50
"	29.	" Baseball Team (balance on account and advance).............	175.00
May	6.	" Lacrosse Team........	30.00
"	6.	" Wiggins & Abell, hardware.......	4.24
"	15.	" Lacrosse Team.......	25.00
"	20.	" Lacrosse Team (on account and advance)..	100.00
"	27.	" Boehm Bros., (Field Day programmes)...	9.00
June	1.	" Athletic Team (expenses to Berkeley Oval)....	1.20
"	1.	" Guarantee to Rutgers B. B. Team and balls	19.00
"	6.	" Hawkins, lumber, etc.	1.90
"	15.	" Baseball Team...	15.00
"	15.	" Dues to Met. Lacrosse League	5.00
"	20.	" George W. Vinten, plumbing.....	7.50
"	24.	" '91 Lacrosse Team photo	1.50
"	25.	" F. Smithson, as per bill	13.00
		Balance, July 1, 1891.....	206.73
			$896.32

'93-'94 BASE-BALL GAME.—The game between the two classes came off Monday, June 1. '94 was beaten from the start, being utterly unable to hit Simpson, who distinguished himself by striking out 20 men. '93 won easily by a score of 15 to 4.

TENNIS.—W. O. Ludlow, '92, is tennis champion of the Institute for another year. The finals in the class series resulted as follows:

'92, Ludlow beat Post, 7-5, 6-2, 6-2; '93, Braine beat Adams, 6-0, 6-1, 6-4; '94. Maynard beat Gibson, 6-1, 6-2, 6-3.

Braine then won from Maynard, 6-1, 6-1, 9-7; and Ludlow beat Braine, 6-4, 6-3, 6-1, winning the championship.

X. Φ. vs. X. Ψ.—The base-ball game between these two fraternities resulted in a victory for the latter by a score of 4 to 3. But five innings were played, on account of the *X. Ψ.* reception given the same afternoon.

CAPTAINS FOR 1891-92.—W. E. Strong, '92, has been elected base-ball captain for the season of 1891-92; K. L. Martin, '92, lacrosse captain, and P. Mackenzie, '93, foot-ball captain.

INSTITUTE NOTES.

PROFESSORS WOOD, WEBB, DENTON AND JACOBUS, attended the Providence meeting of the American Society of Mechanical Engineers, June 16 to 19, 1891. Among the papers read at this meeting were the following:

"Flexure of Thin Elastic Rings." By Prof. Wood.

"Jet Propulsion." By Prof. Webb.

"Performance of a Steam Reaction Wheel." By Prof. Webb.

"Comparison of Economy of Compound and Single Cylinder Corliss Engine." By Prof. Jacobus.

"Performance of a Pumping Engine Against a Head of 2,000 Feet of Water." By Prof. Denton.

PROF. LEEDS addressed the Chamber of Commerce of Rochester, N. Y., May 11, 1891, on the subject of "The Purification of Water by Mechanical Filtration."

DURING MAY, Prof. Stillman was engaged as an expert to examine and report upon several mineral deposits located near Lake George, N. Y. He has also recently been employed to determine the amount and quality of the clay deposits situated at Montrose Point, near Peekskill, N. Y.

AN ENLARGED and revised edition (fourth) of Prof. Wood's Thermodynamics, has been recently issued by Wiley & Sons.

PREVIOUS TO HIS DEPARTURE abroad, Mr. Andrew Carnegie was the guest of President Morton. During a brief inspection of the Institute's shops, he noted the business-like manner in which the work of the shop was conducted. In the evening he dined with President Morton.

IN THE *Engineering and Mining Journal* of May 16 and 23, was published Prof. Denton's paper on "Performance of a Seventy-five Ton Refrigerating Machine of the Ammonia Compression Type," which was presented at the Richmond meeting of the American Society of Mechanical Engineers, November 1890.

FRESENIUS' QUALITATIVE CHEMICAL ANALYSIS has been substituted for Fenton's Qualitative Chemical Analysis as the text-book in the chemical laboratory, with the request that students use the German edition.

PRESIDENT MORTON and family are occupying their summer residence in the Catskills, at Pine Hill, Ulster Co., N. Y., where they expect to remain until college reopens.

PROF. AND MRS. MAYER AND PROF. AND MRS. LEEDS sailed for Europe on June 19, to spend the summer months abroad.

THE EXPERIMENTAL EXERCISES constituting the work given to the Juniors, during the Supplementary Term, are steadily increasing. The new exercises added, during the present term, are the following: Experiments with air compressors, experiments with air refrigeration, Westinghouse Steam Loop, Baker Blower, friction of water through long pipes under heads of upwards of 300 feet, and experiments with ejectors and exhaust injectors. The total number of exercises is now 34. The improvements in the system of instruction still enable all the students to complete every exercise with all the attending calculations, individually, without any extension of the time.

This course is now being taken by special students, instructors in other schools and from the ranks of practice, who attend solely to secure the advantages of this course for their respective fields of labor.

A PART OF THE SUBJECT-MATTER of "Appleton's School Physics," issued recently by the American Book Company, was prepared by Prof. Mayer.

THE DEPARTMENT OF TESTS was engaged upon an increased amount of work during the past year, representing a cost of over $10,000.

Among the extensive investigations made is one, just being completed, which is expected to be of considerable value; this is a very elaborate series of experiments on trap syphonage, which has occupied the attention of the Department for over a year.

PROF. M. SCHROTER, the most active member of the Refrigerating Machine Commission, experimenting with the special experimental station at Munich, established to investigate refrigerating machines, has sent to the Institute the report of the experiments to date made by the Commission, in exchange for the tests made by the Department of Tests on the refrigerating machine at the Knickerbocker Brewery. At the request of Prof. Schroter the special meter, used by the Department of Tests, to measure liquid ammonia, has been loaned him for a year, the Bavarian Commission not having as yet determined the quantity of ammonia circulated in refrigerating machines, which appears to have been subject to measurement, for the first time, in the experiments at the Knickerbocker Brewery.

A COMMITTEE OF THE FACULTY has been appointed to consider what changes can be made in the roster to relieve the work of the Junior Year. It is proposed to advance work of the Sophomore and Junior Years to the Freshman and Sophomore Years, respectively.

THE "LINK" FOR 1891 was issued early in June. It resembles, in its general features, the annuals of previous years. The cuts are well executed and the literary matter is up to the usual standard of merit.

The editors are: Wm. E. Strong, W. B. Everitt, W. B. Powell, Wm. O. Ludlow, Geo. L. Manning, F. H. McGahie, and D. W. Blake. Copies of the "Link" can be obtained from the Editors at $1.00 per volume.

The Mechanical News, May 15, 1891, contains a copyrighted article by Prof. Wood entitled "Try it and See."

BETWEEN 40 AND 50 STUDENTS of the Stevens School have passed their final examinations for admission to the Institute next September, free of all conditions.

INSTITUTE PERSONALS.

'75.

THE ADDRESS OF I. N. KNAPP is 66 Fairview St., New Britain, Conn.

'76.

E. B. WALL was married to Miss Fanny Mitchell, daughter of Mr. and Mrs. John G. Mitchell, at Trinity Church, Columbus, O., on Wednesday, June 24, 1891.

A. W. STAHL, U. S. N., is located in Office of Naval Constructor, Superintending Hulls of Vessels for U. S. Navy, Union Iron Works, San Francisco, Cal. These works are just completing a double turreted monitor, and are about to build a protected cruiser of 6,000 tons, and a battle ship of over 10,000 tons. The three ships represent a cost of about six million dollars. Mr. Stahl is occupied in the superintendence of the construction of these vessels, in preparing the detailed plans, adjustment of the cost to be paid by the U. S. for any changes from contract, etc., etc. He is also a member of a Board of Inspection for the men-of-war, before they go to sea and on returning from a cruise, and is a member of a Board appointed to prepare plans for converting the fast iron steamers of the coast into auxiliary naval vessels in time of war. These plans are filed at Washington for use at any time.

'78.

FRANK C. JONES, Mechanical Expert and Superintendent of Factories for N. Y. Belting and Packing Co., and Manager for Intern. Okonite Co., was elected to Membership in the Amer. Soc. of Mech. Engineers.

'79.

MAUNSEL WHITE, who is in charge of the Testing Laboratory of the Bethlehem Iron Co., has designed an improved form of air bath, a descrip-

tion and cut of which was published in the *Journal of Analytical and Applied Chemistry*, Easton, Pa. June, 1891. The advantages claimed for this bath are, better utilization of heat, uniformity of temperature throughout the bath, and ease and convenience of manipulation.

'80.

THEODORE A. ELLIOTT, Mechanical Engineer, is located at corner of Eagle and Adams Sts., Buffalo, N. Y.

'81.

WM. T. MAGRUDER was married to Miss Ellen F. Malone, daughter of Mr. and Mrs. Thos. H. Malone, of Nashville, Tenn., on Thursday, June 18, 1891.

EDWARD E. MAGOVERN was married at New York on June 20, to Miss Hortense Lacharie, daughter of Mr. and Mrs. Elly Lacharie.

H. C. WHITE is on a trip to Salt Lake City and the Pacific Coast in the interest of the Phœnix Iron Works.

The following account of the construction of two furnaces by Enos L. Moore appeared in the *Manufacturer's Record*, Baltimore, Md., April 18, 1891: Mr. Enos L. Moore, the engineer and contractor of Grand Rivers, Ky., who has the contract for the construction of the two furnaces there, bound himself to build them in a remarkably short space of time—in less time, in fact, for two furnaces than one furnace has ever before been built in, Mr. Moore thinks. Furnace No. 1, under the contract, must be completed within six months from the date of the contract, and furnace No. 2 must be completed 29 days later. If the furnaces are not ready for the company at the stipulated time, the contractor forfeits the sum of $5,000 from the contract price for each additional 30 days required to finish them. Besides these unusual conditions Mr. Moore gave bonds in the sum of $10,000. He is making rapid progress on the work and expects to have both furnaces ready soon enough to avoid the loss of the forfeit money. A well-organized force of 100 men is in the field and works from daylight until dark when the weather will permit. From 35 to 40 car-loads of furnace material are required every month until the work is completed. If Mr. Moore accomplishes his task he will beat the record of furnace building. This is the kind of hustling that tells in development work, and it will be a big card for Mr. Moore and also for Grand Rivers to have two furnaces that lead the record in the shortness of time in which they were built.

EDWARD E. MAGOVERN is general manager for the U. S. of the Edison Phonograph Toy Mfg. Co., 15 Dey Street, New York City.

'82.

CHARLES W. SCRIBNER was married to Miss Helen E. Vail, daughter of Mr. Mahlon Vail, at Grace Church, Plainfield, N. J., on Tuesday, June 30, 1891.

PIERCE BUTLER is the Chief Draughtsman for the Louisville and Nashville Railroad, Louisville, Ky.

'83.

F. A. Magee is located at 126 Pearl Street, Boston, as the representative of the Engineering Equipment Company, of New York, contractors for steam and electric equipment materials.

E. Duque Estrada is associated with Messrs. Kenyon & Gray, inspectors of iron and steel, Lewis Block, Pittsburg, Pa.

'84.

Frank Van Vleck is with the Pacific Railway Company, at Los Angeles, Cal.

The address of Henry S. Prentiss is 1264 Waverly Place, Elizabeth, N. J.

H. L. Gantt read a paper on "Steel Castings" at the Providence meeting of the American Society of Mechanical Engineers, June, 1891.

'85.

Thos. G. Smith is located with R. Vincent & Co., 15 Cortlandt Street, New York City.

Anson W. Burchard was promoted to Full Membership in the Amer. Soc. of Mech. Engineers, at the Providence meeting, June, 1891. Mr. Burchard has been with the J. M. Ives Co., Danbury, Conn., since graduation, and for them he has designed several mills, hat factories, and an electric light station, these structures having been erected under his supervision.

'86.

The Field Engineering Company, with general offices in the "Central Building," foot of Liberty Street, New York City, has issued an 8-page card circular containing useful data on electric railway construction, including cost of electric street railroad equipment, the relative commercial economy of high speed, single, compound, compound condensing and triple expansion engines, and of Corliss engines of the different types, etc., etc.

'87.

W. E. Schoenborn is now connected with the Metallurgical Division of the U. S. Patent Office, Room 149, Washington, D. C.

The Moore Electrical Mfg. Co., Jas. H. Bates, Vice-President, has removed from 106-108 Liberty Street, to Trio Building, 652-654 Hudson Street, New York City.

'88.

Embury McLean has organized the McLean Engineering Company, Consulting and Contracting Engineers for Steam and Electric Plants, Steam Fitting and Edison Electric Motors, Electrical Exchange Building, Room 601, 136 Liberty Street, New York City.

Chas. V. Kerr is Professor of Engineering at the Arkansas Industrial University, Fayetteville, Ark.

Messrs. Thomas, Shepard & Searing, Mechanical Engineers, at Denver, Col., made an interesting series of tests, last December, of the fire-

proof qualities of floor arches of different materials, for the Denver Equitable Building Company, Denver, Col. The *American Architect and Building News* of March 28, 1891, contains the complete report upon these tests, and says, in regard to them, that they were made in a very satisfactory and able manner. The temperature in the furnaces used to heat the arches, was determined by means of platinum wire connecting the furnaces with suitable instruments for measuring the resistance.

'89.

WM. D. PALEN is in the employ of the Link Belt Engineering Co., Nicetown, Pa., since May. His permanent address is 2130 Camac Street, Philadelphia, Pa.

RICARDO J. ECHEVERRIA, Assistant Engineer Third Avenue Cable Road, was elected to Junior Membership in the Amer. Soc. of Mech. Engineers, at the Providence meeting, June, 1891.

'90.

HARRY P. JONES has resigned his position in the Civil Engineer's Office, U. S. Navy Yard, Portsmouth, N. H.

E. H. WHITLOCK has been appointed to the Chair of Mechanical Engineering at the South Dakota Agricultural College, Brookings, South Dakota.

JOHN S. DEHART, JR., has entered the employ of the Isbell-Porter Co., of Newark, N. J. His residence is at 8 Paulmier Place, Jersey City, N. J.

ALFRED F. NATHAN was elected to Junior Membership in the Amer. Soc. of Mech. Engineers, at the Providence Meeting, June, 1891.

'91.

CHARLES H. MCCULLOUGH, JR., has entered the employ of the Illinois Steel Co., South Chicago, Ill.

JULIAN C. SMITH, is assistant to William R. King, '86, General Manager of the Florida Rock Phosphate Co., Ocala, Fla.

LOUIS ELSON is Superintendent of the 14th Street shops of the Hoboken Ferry Company.

THE CORPS OF INSTRUCTORS during the Supplementary Term, in the Department of Experimental Mechanics, included C. G. Atwater, Jesse A. Davis, A. W. Erdman, W. A. Field, Fred. T. Gause and J. M. Hansen, Jr.

L. H. NETTLETON is in the employ of Gillis & Geoghegan, steam heating contractors, 116 Worcester Street, New York City.

ANTHONY KENNEDY is located with the Balt. & O. R. R., at the Mt. Clare shops, Baltimore, Md.

GRISWOLD KNOX accepted a position with the Camden Iron Works, Camden, N. J., about a month before graduation. During the present month he expects to have charge of the erection of a gas holder of a million cubic feet capacity, at Cleveland, Ohio, for the above works.

'93.

LEWIS C. BAYLIS will finish his course at Berlin, Germany.

BOOK NOTICES.

ACCESSIONS TO INSTITUTE LIBRARY, JANUARY 1 TO JUNE 30, 1891.

By Purchase:

Treatise on Steam Boilers and Engines. D. K. Clark, 1890. 4 Vols. London: Blackie & Son.

Evaporation of Liquids by the Multiple System. J. Foster, 1890. New York: D. Van Nostrand Co.

Anleitung Zur Chemischen Analyse. Dr. H. Will, 1883. Leipzig: C. F. Winter.

Transactions of the Inst. of Naval Architects, 1860 *to* 1890. London: H. Southeran & Co.

Index to Transactions of the Inst. of Naval Architects, 1860 *to* 1880.

Die fetten Oele. Dr. Geo. Bornemann, 1889. Weimar: B. F. Voigt.

Untersuchungen der Fetten Oele, Wachsarten, und der technischen Fettproducte. Dr. C. Schaedler, 1890. Leipzig: Baumgartner.

Quantitative Chemical Analysis. Dr. Fresenius, 1876. London: J. and A. Churchill.

Qualitative Chemical Analysis. Thorpe & Muir, 1890. London: Longmans, Green & Co.

Water Analysis. E. Frankland, 1890. Philadelphia: Presley Blakeston.

Qualitative Chemical Analysis. Dr. Fresenius, 1887. London: J. and A. Churchill.

Practical Treatise on Gearing. Brown & Sharpe Mfg. Co., 1887. Providence.

Steam Boilers. Wm. N. Barr, 1880. Yohn Bros. Indianapolis.

Modern Steam Engines. Joshua Rose, 1887. Philadelphia: Baird.

The Century Dictionary. Vol. 5. New York Century Co.

Jahres Bericht uber die Leistungen der Chemischen Technologie. Dr. F. Fischer, 1889. Leipzig: Otto Viand.

Berichte der deutchen Chemischen Gesellschaft, 1868 *to* 1890.

Zeitschrift fur Analytische Chemie.

Analyse der Fette und Wachsarten. Dr. R. Benedikt, 1886. Berlin: Julius Springer.

Specifications and Drawings of U. S. Patents: January to April, 8 vols.

Experimental Science, 1889. New York: Munn & Co.

London Chemical News. Vol. 62.

Scientific American, 1891. Vol. 63.

Scientific American. Supplement, 1891. Vol. 30.

London Engineer. Vol. 70.

London Engineering. Vols. 50, 51.

London Electrician. Vol. 25.

Nature. Vol. 42.

Journal of the Chemical Society. Vols. 57 and 58.

Annales de Chemie et de Physique. Vol. 21.

Annalen der Chemie. Vol. 250, Parts 1, 2, 3, 4, 5, 6, 7, 8, 9.

Hand-Buch der Anal. Chemie. Vols. 1 and 2.

Proc. Am. Assn. for the Advancement of Science. Vol. 38.

Cyclopædia of Quantitative Chemical Analysis.

Journal of the Franklin Institute. Vol. 100.

A Practical Treatise on Animal and Vegetable Fats and Oils. Brannt. Philadelphia: Baird.

Aluminum, its Properties, Metallurgy and Alloys. J. W. Richards. Philadelphia: Baird.

By Contribution:

From Smithsonian Institute:

The Correction of Sextants. Joseph R. Rogers.

A Clinical Study of the Skull. Harrison Allan.

Index to the Literature of Thermodynamics. A. Tuckerman.

Annual Report of the Board of Regents to July, '89.

Report of the U. S. National Museum.

Index to the Literature of Columbium. Bibliography of the Chemical Influence of Heat.

Mental Overwork and Premature Disease Among Public and Professional Men.—Washington: Government Printing Office.

From U. S. Patent Office:

Annual Report of the Commissioners of Patents. Washington: Government Printing Office. T. C. Mendenthall, Supt.

U. S. Coast and Geodetic Survey.—Washington: Government Printing Office.

From V. H. Winchell:

Geological and Natural History Survey of Minnesota.

Washington Observations. 1885. Washington: Government Printing Office.

From War Department:

Annual Report of the Chief of Engineers of the U. S. Navy to Secretary of War.

From A. W. Greely:

Report of the Chief Signal Officer.

From Gen. D. W. Flagler:

Report of the Chief of Ordnance.—Washington: Government Printing Office.

From William Harkness:

On the Progress of Science. Washington: Judd & Ditweeller.

Refraction in the Principal Meridians of a Triaxial Ellipsoid. New York: Putnam.

On the Color Correction of Achromatic Telescopes. New York: Putnam.

From E. and F. N. Spon:

A Treatise on the Calkins Steam Indicator.

From Professor Jacobus:

Iron as a Mineral of Construction. William Pole. New York: Spon.

Blow-pipe Analysis. H. B. Nason. Philadelphia: T. E. Zell.

Mechanics. A. W. Smith. New York: Harper.

From Professor Morton:

Illustrated Museum Catalogue of Work Executed by Wilson Bros. & Co. Philadelphia: Lippincott.

From Dr. T. B. Stillman:

Electro Chemical Analysis. Prof. E. F. Smith. Philadelphia: P. Blakeston, Son & Co.

From Professor Denton:

Constructive Steam Engineering. J. M. Whitham. New York: J. Wiley & Son.

Royal Society, N. S. W., Journal and Proceedings.

Teeth of Gears. George B. Grant.

Institute of Civil Engineers. Minutes and Proceedings.

Massachusetts Institute of Technology, Proceedings of the Society of Arts.

Eleventh Annual Report of the Bureau of Statistics of New Jersey on Labor and Industries. James Bischoff.

Michigan State Board of Agriculture.

Index to Michigan Agricultural Reports, 1844–88.

From John M. Rusby:

King's Treatise on Coal Gas. Thos. Newbigging and W. T. Fewtrell, 1882. London: Wm. B. King.

THE STEVENS INDICATOR.

VOL. VIII. OCTOBER, 1891. NO. 4.

COURSE OF LECTURES IN THE DEPARTMENT OF ENGINEERING PRACTICE.

BY PROF. COLEMAN SELLERS, E. D.

III.—LECTURE NOTES ON STEAM HAMMERS AND HYDRAULIC FORGING AND RIVETING.

THE progress of mechanical construction has been marked by periods, as the needs of engineers have called for new methods to meet new wants. You are now beginning life as mechanical engineers, when an important change in methods is attracting attention to meet a call for iron and steel forgings of great weight.

The direct acting steam hammer was proposed by the late Mr. Nasmyth to enable him to forge the large shafts called for by steamship builders when steam was in its infancy, as applied to navigation. The steam hammer invented by him was not constructed by its inventor until some years after French engineers, who had seen his sketch-book, had availed themselves of his thoughts and built the first machine of the kind. They acknowledged having obtained the idea from him, and in the autobiography of Mr. Nasmyth you will find a reproduction of the page of his sketch-book containing the steam hammer as it has since been constructed.

This reproduced page is a speaking argument in favor of sketch-books in the drawing-room, strongly urged in my first lecture in this course. That page has become historical; without it, someone else might have claimed the invention.

The time has now come for something more powerful than the largest steam hammer that has yet been built. The great hammer of Creuzot, 100 tons in falling weight, with a stroke of 16 feet, is not heavy enough to make some forgings that are now called for.

As a striking example of what is wanted, I may mention the bold construction now under way in London, where two steam engines are being built for an electric station. These engines are to drive dynamos with revolving armatures 45 feet in diameter. In writing the notes for these lectures in the city of London, I do so with the detail of this bold engineering venture by a young man, fresh in my mind. Mr. Ferranti, who is only about 26 years old, has ventured on what, to older men, seems a great risk. To use his own words—he is a believer in large machines for steam power, and small machines for electrical purposes. He is, therefore, making his engines of 10,000 horse-power, and on the rim of a fly-wheel, of peculiar construction, he places his succession of copper coils, which pass, in turn, between the poles of his stationary field magnets. These insulated loops on the fly-wheel rim can be coupled up in any way desirable to obtain the voltage that is required for the alternating current. The design of this engine was made boldly, without considering constructive difficulties. The steel shafts, of about 36 inches diameter when finished, required an ingot of 72 tons for each; while the finished shaft may not weigh more than 28 tons. The forgings as furnished weigh over 35 tons, perhaps. When bids were asked for these forgings, Sir Joseph Whitworth's firm and some of the Sheffield steel makers, wanted from one to two years' time to finish them, while one house in Scotland offered, and did deliver them, in comparatively few weeks, and better looking forgings I have never seen. I was naturally curious to know the weight of the hammers used to produce them, but on this point I could gain no information. Here is an example of an engineer accepting such forgings, without knowing the nature of the forging process or the weight of the hammer, which would indicate, in some measure, the value of the forgings.

The reduction of these forgings to the finished shaft will take away many tons of the best worked part of the steel, and no one can foretell the value of what remains unless he knows just how the forgings were made. We can only hope that they were made either by means of a heavy hammer adapted to the work, or by means of a forging press. A steam hammer of 100 tons weight of ram or top is not too heavy to do work of this size, with any feeling of certainty as to the quality of the forging, even to the depth of a few inches under its skin. I have examined the finished shaft and the metal seems very sound.

It is well known that a very heavy hammer of short stroke will make better forgings of a given size than a lighter hammer falling a greater distance, even if the calculated dynamical efficiency of the blow is the same in both cases. The weight of the hammer bar, or tup, should be at least 80 times the square of the diameter of the shaft in inches, 50-inch diameter calling for 200,000 pounds weight of hammer. The knowledge of this principle has led to the construction of the forging presses that now bid fair to take the place of the direct-acting steam hammer. This introduction of the forging press to do work usually accomplished by the steam hammer, marks an era in mechanics.

Of my own knowledge, I can speak to you of methods that have obtained in forging over a period of 56 years, from when forgings were required for machine shops that had not yet a single planing machine, and from the early tilt hammer with its wooden helve, the rude trip hammer, through all the changes in direct acting hammers, both steam and geared, down to this last extension of the forging press for shapes into the forging press of the hammer type.

The many well constructed power hammers that have come to be essential in every forge that has to do with sizes beyond the power of one or two men to work on their anvil, has done away with a method common enough not many years ago, when anchors and such forgings were smithed by hand power only. Then the master smith, striking with his hand hammer, to do little more than indicate the point to be struck by the helpers, directed from six to eight men who, each swinging sledges of the heaviest weight, stood in a circle about the anvil, and striking, one after the other in rhythmical cadence, poured a succession of blows. Each man swinging his sledge to give, say 12 blows per minute, or one blow each five seconds, could so time their strokes, when six men were in the circle, as to give 72 blows per minute or more. For this character of work, when occasionally required, the extra men would be called from the other fires to work off the heat.

Very many power hammers came into the market when their use was most needed, but the hammer many years ago was set aside on special cases for something that approached the forging press in principle.

The study of the power hammer and what it has led to is worthy the careful thought of all mechanical engineers. Patents

innumerable have been taken out for automatic hammers, but very often the inventors of these machines were ignorant of all the forging processes for which they were to be used, and their inventions show that they are not practical smiths.

This is shown in a marked degree in the many direct-acting steam hammers, which serve an admirable purpose in general forgings, but are wanting in their ability to tilt bar steel. It is only by careful study of the purpose to which a steam hammer is to be applied, that a knowledge of the guiding principles can be learned.

Bar steel is hammered from the billet by rapidly running hammers, but such machines must have the ability to strike light or heavy at the same speed of stroke, if possible. Steel is drawn out to nearly the required size while still at a good heat; the hammering must then go on with diminished heat in the bar until it ends at a certain low heat known to good hammersmen. This puts the finish on the bar and insures the best qualities that can be produced by "work." Steel, as it is cast in the ingot, is coarse-grained, and in no way like the fine grain shown in the fracture of the best tool steels. This difference in structure is brought about by means of "work"; this work may be done by rollers, it may be done by hammers, it may be accomplished by squeezers, the temperature of the metal being an important factor, it may be in a manner accomplished by repeated heating to a red heat, and sudden cooling.

It was from a knowledge of this required work that I was led to propose, in the case of a direct self-acting steam hammer, to introduce a throttling valve in the exhaust from below the piston, while the exhaust from above the piston was left free. This simple contrivance enables a quick stroke hammer to give light or heavy blows with the same number of strokes per minute. With the lower exhaust open, the full intensity of blow is obtained; a hammer so running will be able not only to keep the bar up to heat continually, but even with reduction of size of bar, to seemingly increase the heat. By choking the escape of the lower exhaust port the hammer meets the elastic resistance of the steam that cannot escape, and the blow is made lighter to any required degree, while the number of blows per minute remains the same, as the up stroke of the piston has a free exhaust.

To illustrate the effect of rapid, heavy blows, in keeping up the heat of the steel, you can consider the action as very like what is

shown as a feat of skill accomplished by a smith who can, by rapid blows, heat a cold nail rod to such a degree as to light his pipe or his forge fire. In showing the action of a quick running, small steam hammer used in tilting tool steel, the hammerman after drawing out a bar at a good heat, will quench or cool one end and then, by rapid, heavy blows, that reduce the end to a small rod, reheat it at once to a bright red heat by concussion. This exhibition of what can be done, teaches little to the astonished looker-on, but to the mechanical student it is an important illustration of a physical fact that is worth remembering.

When a limited amount of work is required to shape steel that has already had work put on it, this work can be done to advantage by a squeezer. Thus, makers of steel hand and sledge hammers use a forging-press that is simple and very effective.

The machine for this purpose has a row of dies placed side by side on a bed-plate of sufficient length; over this and parallel with it is a cross head carrying similar dies. The cross head operated by pitmen from cranks or eccentrics driven by gearing from the pulley fly-wheel, has an amount of motion adapted to the work to be done. The steel bar to be wrought, heated to a moderate forging heat, has an oval hole punched through it by one pair of dies, then the hammer is formed by other dies so gauged and shaped as to result in the finished forging of a hammer being cut loose from the bar between the last dies of the row; the number of dies required depending upon the shape of the required forging. Hammers, from the smallest size to a smith's sledge hammer, are thus made, good in quality and low in cost.

The Rider forge is another kind of forging press; but it has a row of separate plungers with a short stroke, each operated by an eccentric. The eccentrics are set, if six in number, at 60 degrees between each. The motion is rapid, say about 600 strokes per minute, ⅝-inch stroke; a certain amount of elasticity being given to the lower dies by plungers packed with cork, the lower dies are adjustable by screws and gearing so as to be set up from time to time, thus enabling a very short stroke to cause considerable reduction of size. This press is a hammer as to rapidity, but a hammer of a fixed stroke.

The drop press is useful when a shape can be produced by a single blow. Each and all of these machines have their places, but their out-put requires consideration if we examine the quality of the work done by them.

There is room for much investigation by means of carefully conducted experiments, to determine the physical changes that take place in the metal under the several modes of forming or deforming the metal by means of:

(*a*) A heavy hammer and short stroke as compared to weight of the metal being forged.

(*b*) A light hammer of longer stroke of the same dynamical effect.

(*c*) Forging by the squeezer that forms by a succession of shaped dies.

(*d*) By the drop press or work done by one blow.

(*e*) Forging by a press that causes red hot metal to flow by means of pressure into the intricacies of a closed die.

(*f*) Forging in a press that has the power to cause at each stroke only a limited amount of deformation, similar in amount at each stroke as would be done by a given weight of hammer falling a given distance.

This brings us to the state of the art that belongs to the new era in forging, and opens up a subject of immense importance to the constructing engineer.

The impression made by a falling weight varies with the heat and consequent softness of the metal, as also upon the extent of the surface covered by the hammer face, weight of hammer, "tup," and length of stroke, etc. A number of experiments, carefully conducted, to determine the required force of a press to simulate the hammer action as to amount of deformation, has led to the conclusion that an ingot of cold lead is about as hard, or as soft, as a steel ingot at a bright yellow forging heat. Experiments conducted with hot metal are less uniform, on account of the cooling of the metal in small mass in a slow moving press.

The very great cost of large steam hammers, their disturbance of the neighborhood by the concussion, the suddenness of the blow, give too little time for penetrative effect. The well-known fact that all forgings are more deeply deformed on the part struck than on the anvil side of the mass, all point to the desirability of deforming by pressure rather than by impact.

Sir Joseph Whitworth was one of the first, if not the first, to avail himself of the press for very large forgings.

The duplex hammer in varied form has not been well received, or had extensive use outside of the shop of the inventors. By

duplex hammers I mean two horizontal acting hammers striking simultaneously on opposite sides of the metal. In this case the anvil and its heavy foundation is dispensed with, and the two hammers act horizontally on the metal carried on an intermediate support. Such machines are complicated and rather inconvenient to handle.

The forging press of Sir Joseph Whitworth is based on the hydrostatic press of Bramah. It is to all intents and purposes the Bramah press to which has been added a new movement, that of the pressing cylinder itself to and from the work, independent of the stroke of the pressing ram. By this movement of the pressing machinery a short working ram is made to operate on masses of varied thickness or height above the anvil. The working power is obtained by means of pumps driven by a crank shaft carrying directly or through gearing a fly-wheel of considerable power. The successive compressions are limited in amount, and the engine driving the fly-wheel is so proportioned as to be capable of restoring the velocity lost by the wheel in each compressive action. The fly-wheel in this instance acts as the reserve of power, as it does in punching machines, when the belt power would be wholly inadequate to do the work but for the aid of the stored energy in the fly-wheel.

I must here digress for a moment to call your attention to an example of ignorance coming from too much knowledge. I had a letter from the purchaser of a punching and shearing machine, who complained that a press intended to punch ½-inch plates was barely able to punch ¼-inch iron. He stated that he had given to the press more power than the starting up directions had called for, "knowing as I do," he said, "that as with pulley blocks and the like, the slower the motion of the weight the greater the power of the combination; I have, therefore, speeded the driving pulley at 100 revolutions per minute, and not at 150 as your card called for, thus giving it all the advantage of increased power." This circumstance would have made little impression upon me but for the persistence of this well-informed, practical mechanic in his refusal to accept my assertion that the press required more belt speed to enable it to do its work. You will meet with many examples of this kind of want of knowledge that must be met not by dictatorial contradiction, but by careful and well-worded explanation that leaves no wounded pride.

You will meet many men who will claim merit as *practical* mechanics, and who will boast of their little book-learning. You will

sometimes be helpless in argument with them until you, too, have had some years of practice to show, as an offset, to what they will persist in calling want of "real practical knowledge."

I would urge upon you the desirability of cultivating a style of argument that will give no offence to those who are strong in their ignorance. But to return to our subject.

It is in the design of a forging machine of this kind that your scientific knowledge will aid you greatly. If you can find out how much power is required to do the work, you can, with absolute certainty, proportion the driving machinery to the work. To put you in the way of deciding on what is wanted, I will state that in several cases I have had to determine the amount of power required to compress hot metal in closed dies and in a press where the metal has room to spread sideways under compression. This latter is the condition usually obtaining with hammer work.

A series of experiments to determine the power required to crush ingots of steel into form for tire making, showed how much less force is required to do the same work in a press than under a hammer.

A number of blocks of lead cast from the same ingot were prepared. Some of these were treated under a hammer of the Morrison type. That is to say, a hammer in which the piston rod is the hammer acting as a ram This piston rod, or hammer bar as it is called, passes through a steam cylinder, is larger in diameter below the piston than above, and the upper end of the bar is capped over so that the steam pressure required to lift the bar is confined to the annular difference between the diameter of the lower end of the ram and the diameter of the steam cylinder; while the steam that enters to drive the bar down acts over the whole area of the piston. In this particular case the hammer bar was, say 5 inches diameter, the steam cylinder, 10 inches diameter; steam pressure about 70 pounds per square inch. Total available stroke, about 22 inches, which is diminished by the height of the ingot receiving the blow. Noting the steam pressure by means of a card of an indicator attached to the upper end of the cylinder, full steam was given to drive down a bar which weighed of itself 500 pounds. It took, under these circumstances, a number of blows to make an ingot that was $3\frac{3}{16}$ inches high and 3 inches diameter, into a plate $\frac{5}{8}$ inches thick and $6\frac{1}{2}$ inches diameter. The thickness after each blow being carefully measured, the extension sideways also, the actual length

of stroke, the mean pressure of the driving steam was noted and tabulated, giving the foot-pounds of work performed and the work per square inch of surface exposed to pressure. See paper by me on this subject in the STEVENS INDICATOR, January, 1889.

To compare this work with that of a press, the similar blocks of lead were placed in a press which had the ability to cause the total amount of reduction at one continuous operation. This, however, was not done, but they were compressed to thicknesses as nearly the same as those produced by the hammer blows; all particulars of the pressure being noted.

From these experiments, we concluded that a press capable of exerting from 3.000 to 4,000 pounds pressure per square inch of surface acted upon, is quite sufficient to deform hot steel when the mass is free to expand sideways.

Four thousand pounds per square inch is not enough, however, to cause hot steel to flow in a closed mould and to fill all corners. To determine the pressure required to do this kind of work, a cylinder was prepared having two plungers, one entering from each end. Into this cylinder, between the two plungers, a hot bar of square iron was placed and a given load applied, amounting to 3,000 pounds to each square inch of the arc of the plunger end. This caused the metal to flow and to partly fill the cylinder. The piece was reheated, and again acted on, while a new square billet was also tried; in both cases the load being increased by 1,000 pounds and the effect noted.

A satisfactory filling of the mould was not accomplished until a pressure of 15,000 pounds per square inch was reached; and from this up to 20,000 pounds per square inch was required in some cases to fill the sharp corners.

I am satisfied that a compressing machine to act in closed dies must be calculated on a power of 20,000 pounds to the square inch on the metal; and this holds also with power riveting machines, where the head is confined by the cupping die and the rivet is to fill all inequalities in the holes that may not quite coincide.

The actual power required to forge by press is about one-third of that required to do the same amount of deformation by hammer; while at the same time, and what is of far more importance, the penetrative effect is very much greater in the press than in the case of the heaviest hammer as compared to the bulk, and far greater still than the penetrative effect of light hammer of high fall on large masses.

Placing a block of lead on your hand, you can with light blows of a hammer deform it to any extent on the surface with a certainty that the interior of the mass is only slightly affected. Experiments of this kind may be multiplied to show the importance of a force that will have time to act on the whole mass of metal, and not merely on the surface.

The direction of modern thought in mechanics is towards the clear understanding of the principles that underlie all manufacturing processes.

In spite of this tendency, however, we have in use constructive operations that will not bear the scrutiny of scientific investigation, and are used without thought only because they have been found to answer the purpose. This applies particularly in the case of machines for working iron and steel while hot by blow or pressure.

The experiment I have cited, where the load was compressed by repeated application of pressure to the same amount of deformation as the hammer used in comparison, was in the direction of what is wanted where direct pressure takes the place of deformation by means of a blow. In working metal under a hammer, the required form is obtained by blows given in succession, each doing as much in the direction of deformation of the original surface as will permit one blow to overlap the work of the preceding blow and so cause the metal to flow under the impact in solid form free from cuts or cracks.

When a bar enters the grooves of a rolling mill it is shaped and extended in length, the part that has passed through the rolls and the part of the bar not yet rolled is marked by a gradation of size grading from one to the other by the shape of the rollers, so with a bar being hammered, the hammer blows if too heavy make too deep a deformation to be quite smoothed out by the next blow without giving rise to a fault or crack.

Some steam engine shaft forgings have failed through excessive deformation, the result of too heavy a blow for the diameter of the work, making too deep a cut at each blow.

We require an amount of pressure that can be controlled by its work and can be made self-exhaustive. The press must not have unlimited power, but have a pressing force that will be exhausted in a short time by its continuance, just as each blow of a hammer ex-

pends all the power or force at each impact. This will give a close imitation of the hammer action without the disadvantage of its suddenness. The press driven by a set of pumps will deform to the extent of the stored power in the fly-wheel of the engine driving the pumps.

Sir Joseph Whitworth's forging machine or forging press, protected by patents, was for some time kept from public view, but what little I saw of it showed me that the patent papers illustrate its theory of operation.

Upon a heavy bed-plate supporting the lower die or anvil are four large steel cylindrical columns arranged in a quadrangle. These columns are threaded at the upper ends for a considerable length, and by means of nuts rotated by machinery a cross-head containing a powerful hydraulic press of limited stroke, the ram acting upon a guided slide to which the top die is attached, and which is lifted to retract the ram, by two lifting cylinders and rams that are fed from an accumulator; while the main cylinder is fed directly by pumps driven by a powerful steam engine with a heavy fly-wheel. The pumping engine is run continuously, with a by-pass for the water when not wanted for compression; automatic valves send the water from the pumps into the cylinder when required. The cylinder, ram and dies are moved in mass to and from the work. the hydraulic press action being confined only to the compression of the metal, to an amount limited by the weight and velocity of the fly-wheel.

A little thought on this subject will enable you to see how closely this action simulates the blow of a steam hammer. The fly-wheel is the storehouse of power. A steam engine, of itself sufficient to give the required pressure, is yet capable of driving a fly-wheel during a period of no work up to speed, and the fly-wheel slowing down to within given limits of speed carries the deformation to the required amount of each stroke.

It is this use of the fly-wheel in connection with direct acting pumps that is the key to the economy of the forging press.

A pressure of say 4,000 pounds per square inch is maintained for a short time by engines that are far from being able to continue the pressure beyond a limited period.

In designing machines of this kind with a full knowledge of what you want you can proportion your machine with considerable certainty far better in effect than is possible in the designing of

steam hammers. The problem is not rendered complicated by shocks and jars that have as yet no fixed numerical value in the equation.

Some makers of forging presses use a stationary ram cylinder with a long stroke in preference to a ram with a short stroke and a movable cylinder carrying the ram, as in the case of the Whitworth press. Devices can be introduced to govern the length of the stroke of the ram automatically. The drop of the pressing ram upon the forging may be effected by low pressure water which is admitted with only sufficient force to give the required velocity to the falling mass of metal in the ram and top die, but as soon as the face of the die touches the metal the pumps may begin to work, or rather the valves give admission from the pumps and shut off the low pressure water, the compressing action is then effected entirely by the pumps to the required amount of deformation called for or possible by the weight of the fly-wheel.

Some very interesting questions have been answered in the designing of these machines. The designer has before him a problem of a structure that must be able to resist heavy strains and yet not complicated, as I have already said, by disturbing shocks and impact.

It has been proposed and carried out in most machines to so construct the framework of the machine which binds the anvil block to the compressing cylinder as to give to the structure a constant binding strain as great as the work that is to be done in the press. This may be accomplished in several ways.

One maker proposes binding the whole of the structure together by overlaying it with a tight band of wire after the manner of building up the wire guns; others to tie them together with bands of steel. After the binding material has been applied, separating the compression numbers—*i. e.*, the side frames or posts, by means of which the top and bottom cross-heads were held apart, and permitting the insertion of wedges so arranged as to take up all the slack in the machine itself. This will make an exceedingly rigid construction, and present a machine built upon the theory of the improved built up guns which are bound together by a force approximating what will be applied in the explosion of the powder in it.

I would like to call your attention to the troubles that have come from faulty design in steam hammers where the problem is

involved from a want of knowledge of the effect of the blows that these hammers will be required to stand.

When the Morrison type of steam hammer was invented—and by the Morrison I mean hammers having a solid ram which of itself is the piston rod of the steam cylinder of sufficient weight to fulfill the nominal capacity of the machine, breaks occurred in the bar itself usually where it was enlarged to form the attachment of the hammer face. This was in a measure relieved by making the part of the rod below the piston larger than the part above it, but the breaks still continued where the lower enlargement ended in the increased diameter required for the die holder. The break at this point was obviated by making the die holder a separate piece from the hammer bar, which of itself is of uniform cylindrical dimensions below the piston, the die holder being bored large enough to receive a circular wedge between the die holder and the piston rod. This really amounts to carrying the weak point down to the meeting line of the end of the piston rod and the top face of the die.

The slowest growth of improvement took place in the framework of the hammer. Many tons of broken frames were replaced by various makers until the conviction forced itself upon their minds that too great rigidity was not to be looked for; that well placed flexibility, as I mentioned in other places in my lectures, is required to prevent breakages.

This was also notably the case in regard to the stationary riveting machine for steam boiler work, which of itself is a sort of forging machine.

In regard to use of power for riveting steam boilers and similar work, it may be well for you to note with considerable care the experience that has been gained in process of perfecting the machinery for this purpose. The early riveting machines were what were called "bull" machines, in which the riveting power was levers or toggle joints. The objection to this form of machine was that there was no allowance made for an excess of metal in the rivet, or for too little metal in it, so that some of the rivets received too great a pressure if they were put in of extra length, while shorter ones did not receive sufficient pressure to cause them to fill up the holes properly. It was also found that the excessive pressure caused by this mechanical riveter had the effect of stretching the seams so that cylindrical boilers riveted in the circumferential seams were considerably larger in diameter at the joint after

riveting than before, and this stretching weakened the joint at that point. One very lamentable explosion that occurred some years ago was ascribed to the riveted joint due to this excessive pressure.

An instructive experiment may be tried, when you have a chance to do so, as follows: Two strips of boiler plate, say ½ inch thick each, drilled or punched for rivets, should be so spaced that the holes will not all exactly coincide, but yet permit the rivet being inserted without too much driving. Let some of these holes be filled, say alternate holes, by hand driven rivets, the rivet head resting on an anvil so that the riveting hammers can be used to the best advantage. Let the remaining holes be filled by machine driven rivets that have had a pressure of 16,000 pounds per square inch, as measured on the area of the expanded head. Place the joined plates after being riveted on a planing machine, and by means of a parting tool cut through the riveted seam so as to preserve one-half of the line intact and to expose the axis of each rivet in the row. You will find with absolute certainty that the rivets driven by power fill the holes no matter how much they may be staggered, while in the case of the hand driven rivets you will find many corners unfilled. You will find illustrations of this comparison in a paper, by Mr. M. N. Forney, in the *Railroad Gazette* of August 12, 1871, and January 13 and February 10 of 1872, where the full sized seam is reproduced.

Mr. Ralph Tweddle, of England, introduced the hydraulic riveter, that had as its chief novelty an accumulator which could be varied in its power by supplemental weights on the ram, and by means of this adjustably loaded accumulator any required pressure upon the rivet could be obtained with certainty.

The relative advantages or disadvantages of hydraulic riveting as compared to direct acting steam riveters has not yet been settled to the satisfaction of everybody. Makers of both kinds of machines found that a blow was not advantageous in closing the rivets by machinery, not that any harm was done to the rivet itself or to the boiler operated upon, but a very serious difficulty arose to the machines themselves.

Steam riveting machines having a large steam pipe leading to the direct-acting cylinder capable of giving a heavy blow are liable to break, and no matter how the frame is made in regard to form or strength, their durability was very limited, and many

costly experiments had to be tried to get over this difficulty of the breaking of the frame of the machine.

The experience gained by the use of the hydraulic riveter led to a change of the steam riveter, and this change was one that was suggested by myself—viz.: to substitute for the steam pipe as ordinarily attached, so small a tube as to render the admission of steam in quantity sufficient to make a quick stroke impossible. Thus, a riveting machine that previously had been fed with a steam pipe 2½ or 3 inches in diameter, was afterwards fed by one not over an inch in diameter. This made a very considerable difference in the working of the machines, and did away with the deterioration of the machine by reason of blows or the concussion.

The introduction also of the slow-moving ram for the quick-moving one (I am only speaking now comparatively of slow or quick), has permitted the extension of the riveting machine to a size that was scarcely dreamed of by those who first began the manufacture of them.

I can report having seen some recently constructed in which the throat of the riveting machine or the overhang was 17 feet, permitting a length of boiler of 17 feet to be riveted continuously at one operation. It will, in fact, permit double that length for a plain cylinder boiler can be riveted for 17 feet of length and then turned over and the other end riveted separately, but the design of these deep throated riveting machines was to permit the riveting up of the waists of locomotive boilers and the attachment of the waist to the fire-box, as there would be no requirement in plain cylindrical work for such a long line of rivets being driven at once.

It may be interesting for you to know that during my recent visit to England, I found that prejudice against the power riveting machines still obtained in that country with even more force than it has until recently in America, and the best work has been advertised as that being done by hand, while in this country the great feeling is in favor of power riveting, as instanced by such establishments as the Baldwin Locomotive Works, the Pennsylvania Railroad, and other large users of riveting machinery.

From my own knowledge of the case, I am led to believe that the time is not very distant when for all good work power riveting will be required in specifications issued.

Coupled with the process of riveting by power comes the question of the preparation of the boiler plates for the application of the

rivets, and it would be well for you to bear in mind, if you have occasion to select or design any plant for this purpose, that the greatest economy can be obtained by careful consideration of several important items in the process. Thus, for instance, in heating rivets it is quite possible to construct a furnace for heating them that will embody the principle of flame, having a minimum of free oxygen in it. This can readily be done when natural gas or similar gaseous fuel is at hand; but even with ordinary coal the admission of air above the fire can be so regulated as to keep down excessive oxygen, and so have a flame that will not cause the rivets to waste if they are kept at a heat for any length of time, and a good riveting furnace should be able to contain a large number of the rivets—a bushel or more—at the same time kept at a good heat without deteriorating.

In regard to the questions that will be canvassed by all makers of boilers, that of the method of punching or drilling holes is probably the most important. Drilled holes are unexceptionally good; punched holes in wrought iron answer a very good purpose, but punched holes in steel should not be used without reaming them, though it is now a pretty well established fact that if steel plates are punched with a hole rather smaller than required, and these holes are then made larger by reaming them, taking out $\frac{1}{32}$ of metal, that the part of the steel that has been damaged by the cold punch is thus removed and the liability to start and crack from the rivet hole is very much diminished.

Somewhere about the year 1880, or 1881, the Mayor of the city of Philadelphia, upon the petition of interested parties, nominated a commission to propose rules for the governing of the department for the inspection of steam boilers in and for the city of Philadelphia.

It was my good fortune to be one of this commission, and the rules afterwards adopted were essentially those that had been suggested by my study of the subject carried on during a number of years, and in the face of very much opposition from some boiler makers, who objected to having any governmental interference with their work.

During the decade that has passed since these rules were formulated and adopted, sufficient time has elapsed to test their usefulness, and also to point towards any modifications that might needed.

In the rules established at that time, if I recollect rightly, there was no especial rules laid down to regulate the use of low steel, the laws or rules governing the inspection having been formulated for iron and not for steel. The department having in charge the inspection of steam boilers has as yet met with no difficulties on account of this omission, construing the laws to apply to any metal at present used for steam boilers, on the assumption that the so-called steel used for steam boilers is only a grade of homogeneous iron.

There was a clause introduced into these rules that is worthy of your attention,—viz.: that which relates to the ductility and tensile strength of the metal used for boiler purposes. Without giving the exact words of the ordinance that was passed, I may say that a factor of safety of four is only allowed when there is such undoubted proof of every sheet that is used in any one boiler having been tested for quality, and the test prescribed calls for the tensile strength and a certain percentage of elongation to indicate its ductility.

Now, it is in reference to this question of ductility that I would call your attention to the fact that it has been fairly well established that ductility, as measured by total elongation of the specimen before rupture in percentage of its length, should be coupled with a statement as to the diminution of area of the section at the point of rupture. It has been discovered that while a metal may show a ductility that might be expressed by 25 or 26 per cent. as measured by elongation, yet the amount of contraction before rupture differs materially, indicating some difference in the physical quality of the steel. It is now believed that the quality of the steel or iron necessary to bring about very considerable diminution of area due to the ductility, is the result of the way the metal is worked, and has nothing whatever to do with its chemical constituents beyond what is essential for high ductility. It is a condition dependent upon the heat at which the metal is worked at the time that the rolling operation is finished. If the rolling be finished at a high heat, there may be good ductility, but the metal breaks after stretching, without a very great diminution of area at the point of rupture, while, on the other hand, if a metal be finished at a lower heat—if the last passes through the rolls be made with the heat very much below the bright red heat—the same characteristics are given to the steel as are brought about by hammering at a low heat, in finishing bar steel under the trip hammer.

In some important cases it was found to be very difficult to get the superintendents of rolling mills to recognize the fact that the quality depended upon their work, they laying the blame entirely upon the mixers of the metal—upon the chemical department of the steel works—and it was not until the interest of the chemical department was enlisted as against the rolling mill department that the managers of the mills were induced to take the proper precaution to insure good work.

I mention this as an important lesson in the direction of seeking for the cause of certain facts, and for the tact that is necessary in bringing about important changes in manufacturing that are not self-evident in their utility, and interfere in some way with the department where radical changes are most needed.

The whole question of the physical qualities of metal under process of manufacture is one that is worthy of your most careful consideration.

I might mention in this connection, that specimens of drop forgings that have been sent to me for examination recently have shown, that while the metal of the bars of iron from which these forgings have been made is in every respect good in physical qualities, yet the forgings themselves, finished by one or at most two blows at a comparatively high heat, show all the evils of the want of work being put on them, in the coarse, granular fracture with which they break, quite different in appearance from that of the bar from which these forgings were made.

I wish particularly to impress upon your minds the desirability of attending to the difference between the physical conditions of metal induced by the process of working up and the conditions that are dependent upon the mixtures or the chemical quality of the metal itself.

It may not be amiss to say just here that the result of the inspection of steam boilers in large cities, as conducted by proper officers, has proved a very great safeguard to the citizens, inasmuch as the number of explosions has very greatly diminished since the passage of the laws and ordinances relating to the inspection of steam boilers in the city of Philadelphia.

PERFORMANCE OF A STEAM REACTION-WHEEL.*

BY PROF. J. BURKITT WEBB.

AT the Erie meeting, a short note, "Note on the Steam Turbine," was presented, with the object of calling attention to and inviting discussion upon whatever progress is being made in that direction, and in doing so there were described, with the assistance of blackboard sketches, the latest and most successful form of a multiple steam turbine, and also a steam reaction-wheel, or Barker's mill, which did good service many years ago. The latter description was supplemented with an off-hand and very rough calculation of the performance of the wheel and the centrifugal force developed.

Owing to a delay on my part in returning the proof of the discussion and appendix, which I had carefully corrected, the matter went to press as it was. The first two paragraphs of the "Author's Closure" are all that belong to it, and were, with the appendix, written after the meeting. The remaining paragraphs belong to the verbal presentation above alluded to, and should precede the discussion.

The appendix was the result of a request that I would add to the paper an outline of the calculation which was put upon the blackboard. I did so reluctantly. Such rough calculations are of questionable value in print, and this one the more so from the errors remaining in it and the omission of the concluding paragraphs, in which the approximate horse-power was arrived at. To set the matter straight I promised a paper on the more exact calculation of such a wheel, which could not be prepared sooner from lack of time. The paper, with its corrected discussion and appendix, was also published at the time in THE STEVENS INDICATOR, Vol. VI., 1889, page 288.

* Presented at the Providence meeting (1891) of the American Society of Mechanical Engineers.

In the calculation of a steam reaction-wheel there are two things which threaten to make the computation of no value unless they are taken duly into consideration. These are the change in density and wetness of the steam as it escapes through, and the increase of pressure from centrifugal force as it approaches, the orifice. If, however, these things are properly treated, the remaining calculation is quite simple. We will discuss essentially the same problem as before, viz., a 15′ H. P. reaction-wheel, of one foot diameter, with a speed of 4,000 revolutions per minute, and a boiler pressure of 70 lbs., or less, absolute.

CENTRIFUGAL FORCE.

To separate these two things, and thus be able to treat each by itself, we will suppose that the pressure of steam is 70 lbs. absolute and the steam saturated, just inside the orifice, where the centrifugal force has produced its whole effect. The boiler pressure will then be less than 70 lbs. by the amount due to centrifugal force, and this will not be so great as to require more than a first, or at the most a second, approximation thereto.

Evidently the increase of pressure will be no more than the centrifugal force of a radial column of steam 6 inches long and 1 inch square, with a density at its outer end corresponding to 70 lbs, and at its inner end corresponding to the boiler pressure. For a first approximation suppose the steam to weigh $\frac{1}{6}$ lb. per cubic foot, which corresponds to 70 lbs. pressure, then the whole column, containing $\frac{1}{288}$ of a cubic foot, will weigh $\frac{1}{1728}$ lb., which, being divided by $g = 32.2$, gives .000018 of a unit of mass. For every 1,000 revolutions per minute that the wheel may make, the circumferential velocity will be about $52\frac{1}{2}$ feet, and the angular velocity twice that, or 105, and, as the radius to the centre of the column of steam is $\frac{1}{4}$ foot, the centrifugal force of the column of steam is — cent. force = (ang. vel.)^2 $\times$ radius $\times$ mass = $105^2 \times .25 \times .000018 = \frac{1}{20}$ lb., and this would be somewhat greater than the increase of pressure because the density of the column of steam is less toward the centre.

For greater speeds we should have: For 2,000 per minute $\frac{4}{20} = \frac{1}{5}$ lb., for 4,000, $\frac{16}{20}$ or $\frac{4}{5}$ lb.; for 16,000, $\frac{256}{20}$, or say 12 lbs. Therefore, at 4,000 revolutions the boiler pressure would not be a pound less than the nozzle pressure, and no more accurate estimate of the centrifugal force is needed, while at 16,000, if the

effect of the decreasing density of the column toward the centre is to be allowed for, it will reduce the difference of pressure calculated above about 5%. leaving a difference of over 11 lbs. between the boiler and nozzle pressures.

We come now to a more important part of the calculation:

FLOW OF STEAM THROUGH A NOZZLE.

It is not enough to know from a formula how much steam will escape through a nozzle; the way in which it escapes has an important influence on the power developed.

Let Fig. 1 be a nozzle delivering steam of 70 lbs. pressure. In speaking of this pressure as existing at the entrance to the nozzle, say at the point *a*, a slight reservation must be made, so as to allow for the velocity past that point. This velocity is comparatively small; suppose, for instance, that the cross-section at *a* is 10 square inches, while the smallest or "throat" section of the nozzle is 1 square inch, then about 1 pound of steam per second will pass *a** and its velocity will be only·86 feet per second, to produce which a fall of pressure of two ounces would be enough, or if the section at *a* was only 5 square inches there would be a required fall of a half pound to produce the necessary velocity of 172 feet. The 70 lbs. then is 70 lbs. for still steam.

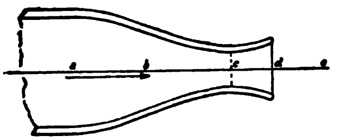


FIG. 1.

No exact solution of the problem can be made until we know the way in which the pressure decreases, as the steam flows from *a* to *e*, at which latter point we shall suppose it to have reached atmospheric pressure. If we had to do with the flow of water, or other non-compressible fluid, the variation of pressure along the route would have no effect upon the result, and we would need to know only the mass of the water delivered per second, and the section of the stream at its point of exit; from these we could at once calculate the momentum per second to which the reaction of the jet is equal. The previous rough calculation was in fact made in this way with an estimated allowance for the increase in velocity due to the expansion of the steam, and as the particular shape of the de-

* For the weight of steam escaping through a 1-inch nozzle at the different pressures, see Rankine's "Steam Engine," page 324.

livery nozzle was not then supposed to be known, it would not have been possible to arrive at a result without some such assumption.

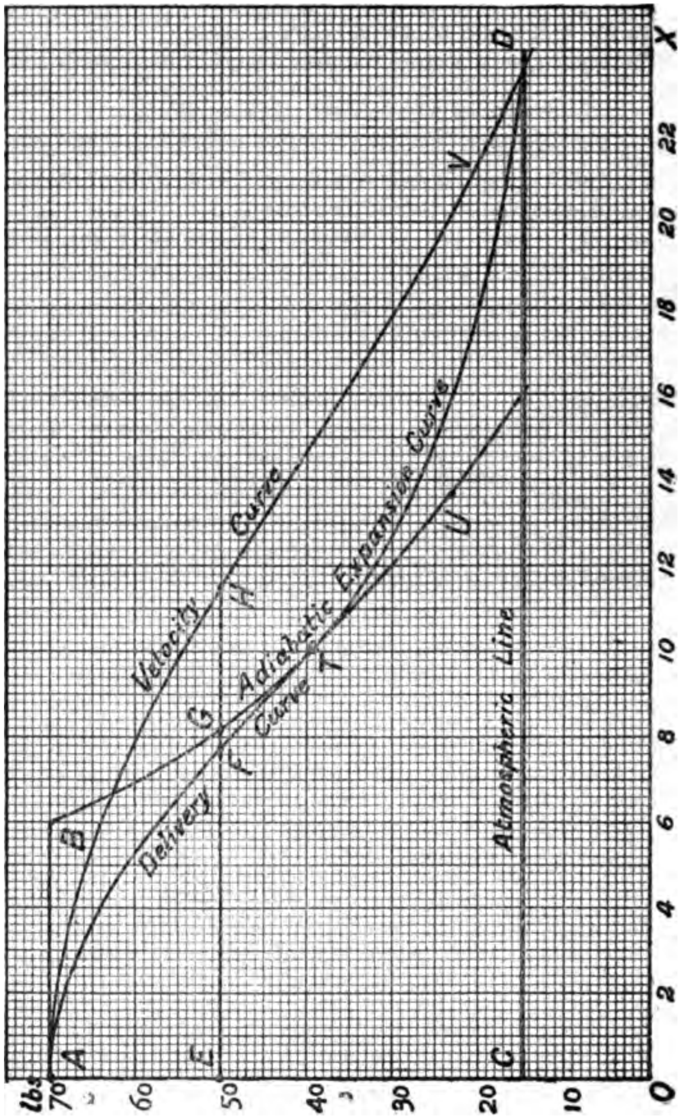


FIG. 2.

In fact, the form of the nozzle governs to a considerable extent the power of the wheel, as will shortly appear.

If the steam passing *a* were to be forced through the throat *c* without any change of density, its velocity at *c* would be the length of a column of steam one inch square and containing six cubic feet nearly, or about 864 feet. But the velocity at any point, as *b*, is to be created by the steam itself, expanding adiabatically between *a* and *b*, which expansion necessitates a fall of pressure and a decrease of density, accompanied by some condensation of steam, and this decrease of density acts unfavorably on the flow, inasmuch as it makes a higher velocity necessary to get the same weight of steam past the point.

The steam, therefore, has a problem to solve; it must expand and get up considerable velocity before it reaches the throat *c*, but there is a limit to the amount of expansion, beyond which its volume, and consequently the velocity it must have to pass *c*, increases faster than the work of the expansion could increase its velocity. This is evident in a rough way by considering that an expansion down to absolute zero of temperature could do but a finite amount of work, while the volume of the steam would then be infinite, requiring an infinite velocity to pass *c*, so that a point must exist between 70 lbs. and 0 pressure, at which the most steam will pass through a given section, and this is the pressure which the steam will maintain at the throat *c*.

Stated mathematically, the pressure at *c* must be such as to make the product of the velocity $\times$ weight per cubic feet of the wet steam passing *c* a maximum. This subject was investigated mathematically by Rankine, and published in the London *Engineer*, in November and December, 1869. Among the cases there considered are saturated steam flowing through a conducting nozzle, and through a non-conducting one, and in the latter case the pressure in the throat is found to be .58 of the pressure behind the nozzle, so that in the present case the pressure at *c* is about 40 lbs. At *d* the pressure will still be considerably above atmospheric. An extract or two from that article will be pertinent here:

"It is quite true, as Mr. R. D. Napier has pointed out, that the ordinary method of using Weisbach's formula is based on the supposition that the pressure at the contracted vein or throat of the jet is the same as in the space into which the gas is discharged"; also,

"Zeuner, near the end of the paper already referred to, considers it probable that the effective area of the jet is in general

greater than the actual transverse area of its throat or narrowest part, in a proportion depending partly on the form of the outlet and partly on the pressure. He makes no attempt to determine from theoretical principles what laws that proportion may follow, and states that those laws are to be ascertained by experiment only."

The first extract shows that this is a subject comparatively new, quite new, I believe, to most engineers; the second, while showing the same thing, indicates that it is a new field for mathematicians.

I propose to deduce, by a graphical method, the law governing the reduction of the pressure in such a jet of steam, arriving thereby at the same result—namely, that with 70 lbs. at the entrance there will still be 40 lbs. in the throat of the jet; and I believe this graphical representation of the facts puts the whole matter in the clearest possible shape and must satisfy any one as to its correctness, although at first, it may seem difficult to believe that the pressure in the throat and at the end of the nozzle can be so much higher than the atmospheric pressure.

Let *ABCD*, Fig. 2, be the theoretical indicator card for the adiabatic expansion of 1 lb. of saturated steam from 70 lbs. pressure to atmospheric. *AB*, the volume of a pound at the highest pressure, can be taken directly from a table, but the remaining volumes must be calculated by the proper formulæ (see Rankine's "Steam Engine," paragraphs 281 and 282, formulæ for u).

It will be simpler if we calculate first the amount of steam going through an area or opening of unity—*i. e.*, one square foot, and the line *AB* will then represent the velocity (6 feet per second) necessary to make 1 lb. of steam at 70 lbs. pressure, that is, to make 6 cubic feet of steam, go through a one-foot square opening. In the same way any other line, as *EG*, represents, not only the volume of a pound of mixed water and steam at that pressure, but the velocity necessary for it to pass through an area of 1 square foot.

We must now inquire into the production of the necessary velocity by the expansion.

The work done in falling from 70 lbs. to any other pressure, as 50 lbs., is given by the area *ABEG*; thus, this area represents about 19,872 foot-pounds, found by multiplying the fall of pressure per square foot by the average volume, or, $= 20 \times 144 \times 6.9 =$ 19,872. Multiplying this by $2g$ and extracting the square root (see Rankine's "Steam Engine," page 298, formula 1), we get 1,131

as the velocity produced by the expansion—*i. e.*, if a pound of steam were to fall by gravity through a height of 19,872 feet, 19,872 foot-pounds of work would be done by gravity and a velocity of 1,131 feet produced as the result. This is the velocity corresponding to 50 lbs., and in the same way the velocity can be found for all pressures on the card. A more exact way is, by means of the formula (1 A), on page 387, Rankine's "Steam Engine."

Let these velocities be laid off to a suitable scale opposite the corresponding pressures, and the velocity-curve AV drawn (the scale chosen is such that figures 2, 4, 6, etc., along OX, indicate 20, 40, 60, etc., feet per second).

A comparison of the two curves shows the following:

At 60 lbs. pressure the pound of steam has a velocity of. 780 and a volume of about seven cubic feet; therefore it must have a sectional area of seven seven-hundred-and-eightieths of a square foot to pass through, because the area $\times$ velocity $=$ volume. At 50 lbs. it has a velocity of $EH = 1{,}140$ feet and a volume $EG = 8.2$ cubic feet, and we get, in the same way, a sectional area of about .007 square foot; at 40 lbs. an area of less than .007 square foot, at 30 lbs. an area greater than .007 square foot, and for 20 lbs., etc., the area goes on increasing. Therefore the jet will naturally assume a shape with the smallest cross section agreeing with the neighborhood of 40 lbs. pressure, and the shape will fit itself into the nozzle if the latter has a shape similar to that of the jet. By a more careful calculation the minimum sectional area will be found at about 40.6 lbs., and will be .0068 square foot, or .98 square inch.

Lay out a new curve of volumes AU, which we will call the "delivery curve," by multiplying all the velocities by the minimum sectional area, thus: EH multiplied by $.98 = EF$. This curve will be tangent to the adiabatic curve at T,* where the pressure is 40.6 lbs., and any volume given by it, as EF, is the volume of steam which will pass through a sectional area equal to the throat section, or .0068 square foot, at the corresponding pressure, or 50 lbs.; therefore, where the steam has this pressure the nozzle must have a sectional area larger than the throat area in the proportion of EG to EF. It does not come within the scope of this paper to show how to lay off a nozzle of the most correct form, but, given such a noz-

* The point T in the figure has, by mistake, been shown just below the 40 lb. line instead of above it.

zle, we may mark the pressure at any point along it, as *b*, Fig. 1, by finding the pressure in Fig. 2, at which $EF : EG$ as the throat section : section at *b*.

The first use to be made of the above discussion is to obtain the size of the throat necessary to pass the quantity of steam desired, or *vice versa*, when the throat is given to find the quantity. If one pound will flow through a throat section of .98 square inch, then a one-square-inch throat will pass 1.02 lbs.; but friction will certainly reduce the flow somewhat, so that we may as well allow 2%, and take one pound as the delivery through one-square-inch throat section, which agrees with Rankine's approximate delivery formula (see Rankine's "Steam Engine," 11th edition, page 298, 3d line from the bottom).

The next use is a much more important one in its bearing on the power and efficiency of the reaction-wheel. If the nozzle be terminated at the throat the steam will be abandoned at 40.6 lbs. pressure; but if it be flared beyond the throat to *d*, so that the section at *d* is about 10% greater than the throat section, then we shall hold on to the steam until it expands down to about 26 lbs., for which pressure EG is 10% greater than EF, and thereby increases the power and efficiency of the wheel.

To calculate the horse-power for these two forms of nozzle we proceed as follows:

In one second one pound of steam escapes, or $1 \div g = .031$ unit of mass, which, multiplied by the velocities for 40.6 and for 26 lbs.—viz., 1,440 and 1,905, give 45 and 59 for the momentum per second, which are the reactions of the jets in pounds. In one minute the orifice *d* of the jet travels $4,000 \times \Pi$ feet; the steam does not, however, issue tangentially, but at an angle α (Fig. 3), and therefore the work done is $45 \times \cos\alpha \times 4,000 \times \Pi$ in the one case, and $59 \times \cos\alpha \times 4,000 \times \Pi$ in the other, and if $\cos\alpha$ equals, say .9, we get respectively 509000 and 667000 foot-pounds per minute, or about 15 and 20 H. P. In estimating the cosine of α an allowance should be made for the divergence of the outer parts of the jet from the direction of its axis.

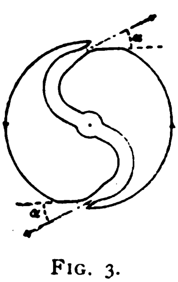


Fig. 3.

The same wheel run at 16,000 revolutions would develop four times the gross horse-power with a boiler pressure of about 59 lbs., as before shown, giving therefore about 62 and 80 H. P., according to

the degree of expansion. By prolonging the nozzle until its outward end has about one and a-half times the throat section, the steam can be expanded to atmospheric pressure with a velocity of 2,300 feet, which would increase the horse-power theoretically to about 24 for 4,000 revolutions, and to 96 for 1,600. That the full theoretical advantage of this complete expansion could be realized in an actual wheel cannot be assumed, as there may be drawbacks which would appear in an experimental test.

In the above calculation we have made no allowance for friction beyond using one pound per second, instead of the somewhat larger discharge indicated by our analysis. But, as in reducing the flow, the friction reduces the velocity, a further allowance should be made for it. This, however, will be different for different sizes, forms and smoothness of nozzles, and we cannot attempt to calculate its effect here.

The horse-power calculated above may be called gross horse-powers, or those actually developed by the steam jets. From these must be made a deduction peculiar to a reaction wheel, but which is avoided in a turbine by means of the entrance guide-blades. All of the steam arriving at the point α has been received by the wheel at its centre with but little velocity, and during its flow outward to α the wheel has given to it the velocity of its periphery, or 52½ feet per second for each 1,000 revolutions per minute. Thus the steam absorbs each second from the wheel an amount of energy equal to the mass per second into half the square of the velocity $= .0\dot{3} \times .5\ (52.5)^2 = 43$ foot-pounds, or about 2,600 foot-pounds per minute. This deduction for the speeds of 4,000 and 16,000 per minute will be respectively 16 and 256 times greater, or 41,000 and 656,000; thus reducing the gross horse-powers per 4,000 revolutions—namely, 16, 20, and 24, to less than 15, 19, and 23; while for 16,000 the horse-powers fall from 64, 80, and 96, to 44, 60, and 76.

The water used, 3,600 lbs per hour, divided by the horse-power, gives from 240 down to 60, and even 48 for the complete expansion.

A comparison of the above results, with those deduced in the rough calculation, sustains the general accuracy of the latter.

DISCUSSION.

Mr. Geo. H. Barrus.—It may be of interest, in connection with this paper, to give the results of tests which I made upon an engine

which depended for its action on the impact of a steam jet striking against the blades of a wheel inclosed in a metal casing. The chamber in which the wheel revolved was about 15 inches in diameter and 1½ inches thick, these being the inside dimensions. The wheel was 14 inches in diameter at the edge of the blades, and the width of the blades was about 1 inch. The steam was admitted through a pipe placed in such a position that the steam struck the blades at a point near the end, and in a direction tangential to the circle. The orifice was ¼ inch in diameter. The quantity of steam used, which was constant, amounted at 100 lbs. pressure, to 210 lbs. weight per hour. The amount of brake horse-power developed when the engine was run at its maximum speed—viz., 6,000 revolutions per minute was 1.2 H. P. Under these circumstances the rate of consumption of steam per brake horse-power per hour was 175 lbs.

Mr. Strickland L. Kneass.—Although I cannot give at the present time any information in regard to experiments with the steam turbine, yet I would like to present some notes upon that part of Prof. Webb's paper bearing upon the discharge of a jet of steam.

The efficiency of a steam reaction-wheel depends upon two principal conditions:

(*a*) The amount of work converted into velocity by expansion of the steam.

(*b*) The application of the energy of the discharging jet to the rotation of the wheel.

The first condition requires, in order to produce the highest theoretical efficiency, that the expansion must be carried down to the pressure of the surrounding medium during its passage through the nozzle, and that with the least possible loss. The second condition has already been covered, and therefore will not be discussed.

The peculiar form assumed by a jet of steam after issuing from an orifice indicates that the laws that govern the discharge may be very complex, and that the shape of the nozzle to develop the maximum energy of the jet is entirely different from the form used for inelastic fluids. The sketches shown in the illustration are based upon observations and photographs of jets at 120 lbs. initial gauge pressure; four orifices of different shapes are represented, each having an individuality of its own.

1. A short cylinder or convergent nozzle. (Fig. 4.)
2. An aperture in a thin plate. (Fig. 5.)
3. A divergent straight taper. (Fig. 6.)
4. A divergent curve. (Fig. 7.)

For the sake of clearness the white part of the discharge is made with dark tones and the visible lines near the orifice are somewhat emphasized.

The first two nozzles permit an immediate diametral expansion and consequent loss of velocity-producing energy; an envelope of

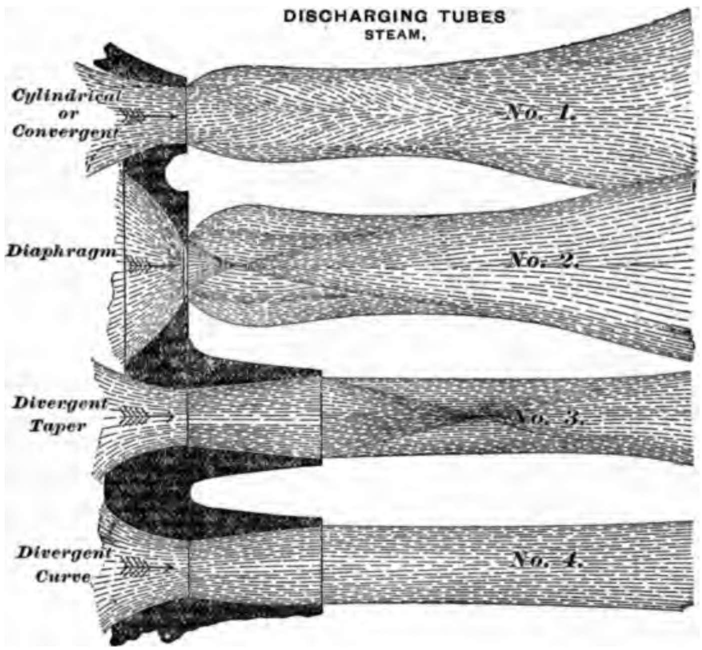


Fig. 4. Fig. 5. Fig. 6. Fig. 7.

low-pressure steam is formed, through which the central jet is clearly seen; this swelling of the jet occurs whenever the internal pressure at the mouth of the nozzle is higher than that of the medium into which it discharges. The appearance of the envelope depends upon the pressure and the percentage of moisture in the steam; when very wet the discharge is almost perfectly white, while dry steam gives a clear, transparent blue with occasional flecks of

white and changes of color, that indicate the boundaries of the internal and external jets.

The divergent nozzles No. 3 and No. 4, on the other hand, compel an axial expansion which utilizes the energy more fully, and if correctly proportioned will give the steam very nearly its theoretical velocity.

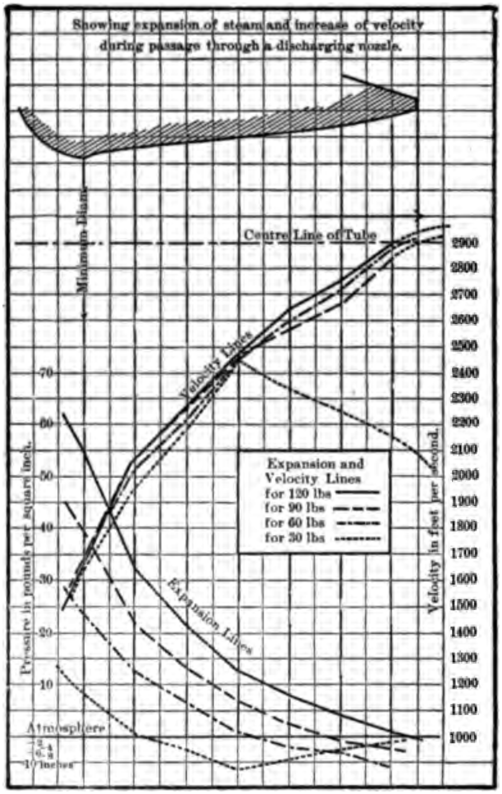


FIG. 8.

Some experiments were made about four years ago upon the internal condition and velocity of discharge of a jet during its passage through the tubes of various shapes, and the results embodied in a paper presented before the Engineers' Club of Philadelphia. Therefore, without going into detail, I will state :t the internal pressure during discharge was observed at

several different points of a tube, and the velocity of the steam calculated for each section. The results correspond closely to those found theoretically by Prof. Webb, and, further to illustrate, I would present a diagram (Fig. 8) showing the expansion of the steam and increase of velocity in a nozzle with divergent curves; pressures and velocities at all points of the tube are shown for 30, 60, 90 and 120 lbs. initial gauge pressures, and the relative length of the tube for any degree of expansion is apparent. The upper lines indicate curves of velocity, and the lower expansion lines indicate the fall of pressure as the steam traverses the tube.

There will be noticed a curious fact to which I have never seen reference made—viz., that the velocity is practically the same at any given section for all pressures from 30 to 120 lbs., making the weight discharged per second almost exactly proportional to the initial density of the steam.

In conclusion I would like to state that the ratio of the absolute pressure at the minimum diameter of the tube, to the absolute initial pressure, was not found to be constant in my experiment, but varied slightly with the pressure; the value of 58%, as given by Rankine and demonstrated graphically by Prof. Webb, would seem therefore to be a mean for all pressures.

Mr. Carleton W. Nason.—I notice there that the best efficiency is about 60 lbs. of water per horse-power per hour, and I believe there is also a considerable percentage of that which has been due to the condensation of steam within the wheel. Take, for example, the instance of the Avery engine, which is a pair of steel plates brazed together at the edges, and running at a very high velocity, the wheels being six feet in diameter. The condensation in that wheel, unless the surface was protected, must have been very large. Experiments that I have made in steam condensation on metallic surfaces show that as the velocity of air or water passing over them becomes high, they increase very rapidly in their transmission of heat and condensation of steam on them.

Prof. Sweet.—I would like the attention of the meeting for a few moments for the purpose of giving a few facts in respect to the Avery engine, and to ask whether the theories advanced by the theorists correspond with the facts as they are known to have existed in the engine. One of the original engines can be seen at the Cooper Institute in New York. It is a machine five feet across the arms, made of steel, with two orifices, each one-twelfth of an inch

in thickness and one-sixth of an inch long. It was reported, and I believe it to be true, that those orifices would permit all of the steam that an ordinary boiler would make to pass through them when the engine was at its maximum speed.

The orifices would not permit all of the steam from the boiler to pass out when at rest, but when under motion they would pass over the steam, and it was for this reason, probably, that all the steam that the boiler could make would go through these two small holes. Probably a hundred engines of this kind were run for a number of years, driving saw-mills, and were at that time a successful machine, at least so the people thought who ran them ; and one machinist, who took out an Avery engine and put in a stationary slide valve engine, said it took just as much wood to run the mill as it did before. The trouble with the Avery engine was, they ran so fast that the second arm came around into the steam as it left the first arm, cutting each other away, so that the arms would not last more than two or three months. While that would not trouble us at all at this day, it was what threw the Avery engines out at that time. The first slide valve engines that were put in to take the place of the Avery engines were not particularly more economical. In Mr. Avery's note book, which I own, he states that in his engine, which was on a locomotive, and started to run from Newark to New York and ran into a ditch, the arms were seven feet from end to end ; that is, revolving in a circle seven feet in diameter, and the outer end of the arm ran at the enormous velocity of fourteen miles a minute.

Mr. Suplee.—I should like to refer to these instantaneous photographs of jets. I notice some similarity between them and some photographs of rifle bullets I saw not long ago, where the object was distinct, as well as the condensation produced in the air made by the velocity of the bullets through the air. The shapes of the curves were very similar to those of the jet, except that when the velocity reached a sufficiently high point the air was very noticeably condensed in front of the bullets. Of course the reaction in the gun would not be affected in the slightest by the subsequent resistance which the bullet might meet in the air, but the shape of the curves in the photographs was very similar to the sketches exhibited.

Prof. Webb.—These experiments with a steam jet seem to me to be most important. A thing which is used as much as steam is and in the economical use of which we are so much interested,

should be used intelligently, and it would seem that large amounts of money might be advantageously spent in learning exactly how steam acts under various circumstances. There is one fact, which was not brought out sufficiently, to which I wish to call your attention, as to the escape of steam from the reservoir, with reference to the amount of steam escaping at different pressures and with different lengths of nozzle. Suppose we have a reservoir and a properly shaped nozzle which permits the expansion of the steam down to atmospheric pressure. Say we have 70 lbs. in the reservoir and 14 lbs. outside at the end of the nozzle. A certain amount of steam will escape. If you cut off this nozzle, so as to shorten it gradually, still, leaving out the effect of friction, the same amount of steam will escape; the surrounding air takes the place of the part cut off the nozzle as long as it is not cut away as far as the throat. Again, if you increase the outside pressure to anything less than the throat pressure, or 40 lbs., you will not affect the flow of steam.

The experiments undertaken by Mr. Kneass are of great interest and of considerable difficulty. Too great dependence should not be placed upon conclusions drawn from the appearance of the jets. Photographic views, even of jets, may require considerable ingenuity to interpret them properly, and may in some points be deceptive, and cuts engraved from them must be more so. I would suggest that the jets should be placed in front of a background ruled in small squares, and this background photographed as it appears through the jets, so as to get at their constitution by means of their distorting effect upon the system of squares. Precaution should also be taken to prevent rotation of the jets, a very natural explanation of the form of such jets as Figs. 320 and, especially, 321 being that the steam escapes in paths approximating to the elements of a hyberboloid of revolution. The curious fact referred to is a well-known one, and lies at the bottom of Rankine's rule for getting the delivery in pounds per second of a jet by dividing the pressure by 70 and multiplying by the section of the jet in square inches.

Some gentleman stated that in a steam reaction-wheel the periphery ought to run at the same speed as the steam escaped, and Prof. Sweet questions whether theory and practice ought to agree when the steam escapes from a revolving wheel.

Theory takes into account the motion of the wheel, and, indeed, the effect of the motion is very simple. Steam will escape just as

fast whether the wheel revolves or stands still, provided the pressure back of the orifice remains the same, but the effect of the motion of the wheel is to increase that pressure by the centrifugal force of the steam in the wheel, this makes the steam denser, with more pressure to force it through the orifice, so that the same orifice delivers more when the wheel is in motion. There is nothing in the suggestion that the wheel moves over or past the steam, thus increasing the flow, because the steam before it escapes is going round with the speed of the wheel; centrifugal force fully accounts for any increased flow. As to running the wheel as fast as the steam escapes, it is impossible to do so with a reaction-wheel, because increasing the speed of the wheel increases the centrifugal force, and, therefore, the speed of the escaping steam, and makes it impossible for the former to catch up with the latter, and this is the fundamental reason why a reaction-wheel cannot be highly efficient, as a turbine can. In a turbine you can make the wheel revolve as fast as the steam escapes. In the calculations I have made in the paper, the greatest difference of pressure due to centrifugal force is 11 lbs. In a steam turbine a fall of pressure of 4 or 5% produces as high a velocity in the steam as the wheel can safely have to keep up with it. Multiple turbines are built which run, say, 9,000 revolutions per minute for a 30 H. P. machine. In these the steam is economized by repeated expansions; there are forty five expansions in the turbine referred to. In calculating a steam turbine, all these points are taken into account in theory except the radiation; and these machines are so much smaller than other engines, that the radiation might be very rapid, and yet but little heat be lost.

It has been suggested that the gyroscopic action of the Avery wheel prevented the locomotive from freely following the curves of the track; of course, to avoid such an action, all that would be needed would be to place the axis of the wheel vertical, in which position it would have a beneficial effect in opposing pitching and rolling of the locomotive.

Mr. Barrus's experiment is very interesting, as it falls in so well with calculation. Of course, 6,000 revolutions was nothing like the speed the wheel ought to have had to do its best.

TESTS OF SCREW STEAMERS "POMHAM" AND "SQUANTUM."*

THESE vessels are small passenger steamers for summer excursion traffic in Narragansett Bay, Rhode Island, built by T. S. Marvel & Co., Newburgh, N. Y., in 1888. They are duplicates of each other in all respects, the principal dimensions and fittings being as follows:

Length...120 feet.
Beam...21 "
Draught..6 "
One compound receiver engine, cranks at right angles, cylinders 14"x26" and 18" stroke, unjacketed.
Valve gear..............Link motion with Meyer cut-off on high cylinder.
Clearance, high cylinder......................8 % of piston displacement.
" low " ....4 % " "
Receiver volume.................. 1.43 times high piston displacement.
Boilers, 2 horizontal return tubular 4 feet 6 inches diameter, 13 feet long, each having 64 3-inch tubes set in brickwork.
Total heating surface..................................1,350 square feet.
" grate " ....49 " "
Ratio grate to heating surface..........................28 " "
Ratio of cross-section of tubes to grate..........................6.8
Feed pump, independent direct acting.........6"x 4"x 5" stroke [actual].
Air pump, " " " ....6"x10"x12" " "
The condenser was of the surface type, with a centrifugal circulating pump driven by a 5"x6" upright engine.
Diameter of screw..5.5 feet.
Pitch " " ....8.25 "

GENERAL METHOD OF MAKING ENGINE AND BOILER TEST.

The main engine and pumps exhausted into the condenser, and the delivery of the air pump was received in a tank having a cali-

* Abstract of Thesis of Messrs. Wildman and Phelps, Class 1890.

brated orifice, so that by observing the level in the tank, the quantity of steam consumed by the entire plant was determined by short trials for various cut-offs and conditions. The consumption of the pumps and circulating engine was then estimated, from the indicated power of each, to be two pounds. The boiler test lasted nine hours. Steam was first raised with wood, and then a new fire laid, and the test started with the ignition of the latter. At the end of the test the fire was well burned out, and all coal remaining on the grates weighed as ashes. Pea coal was used, of a rather poor quality and not very dry.

The principal results obtained are as follows:

	"POMHAM."	"SQUANTUM."
Average boiler pressure, lbs. per square inch above atmosphere	85	87
Average vacuum inches	24	24
" feed temperature, degrees Fahr	95	101
Lbs. coal per hour per square foot grate	12	11.7
Per cent. of refuse	16.0	15.0
Actual evaporation per lb. of coal, lbs	6.8	7.4
Equivalent evaporation per lb. of combustible from and at 212° Fahr	9.0	9.9
Evaporation per square foot of heating surface from and at 212°, per hour	3.4	3.2

A portion of the feed-water was drawn constantly from a fresh water tank, the delivery of the air pump not sufficing for the entire feed to boilers. The air pump delivery accounted for only 90 per cent. of the total feed water, the remaining 10 per cent. being unaccounted for except by miscellaneous invisible leakage. The power to operate the pumps was as follows for an average of 150 H. P. developed by the main engine:

Feed pump	0.45	H. P.
Air "	0.80	"
Circulating pump	2.0	"

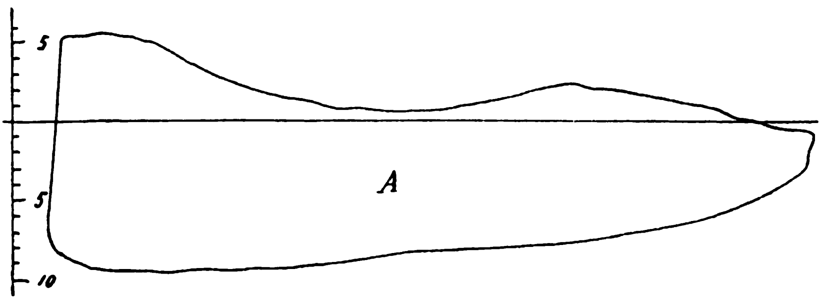
Assuming a consumption of 150 lbs. of steam per H. P. for the direct acting pumps, and 60 lbs. for the circulating engine, the consumption of all three pumps amounts to two lbs. per hour per H. P. of the main engine.

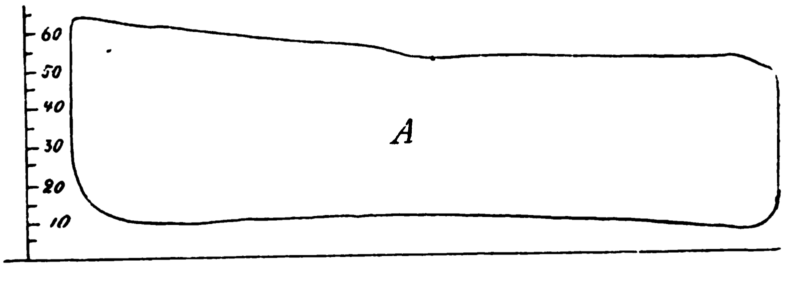
Making this allowance, the economy of the main engine of each boat was as follows:

"POMHAM."

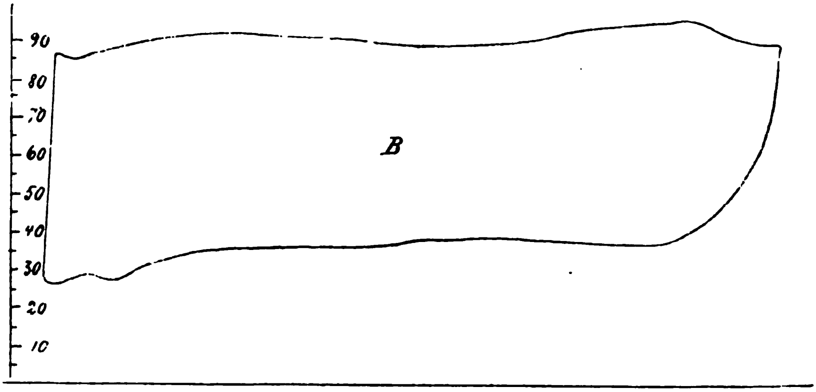
CONDITIONS.	Blr. press.	Indicated H. P.	Revs.	Steam per hr. per H. P.	Coal per hr. per H. P.	Indicator Cards.
18 in. cut-off, throttle partly open.	90 lbs.	162	145	29 lbs.	4½ lbs.	A
Ditto " wide "	110 "	320	180	29 "	4⅛ "	B
9 in. cut-off, " " "	90 "	182	146	21 "	3 "	D
6 " " " " "	95 "	151	134	20 "	2.85 "	C
"SQUANTUM."						
Throttle partly open.	85 lbs.	115	126	32 lbs.	4.1 lbs.	
" wide "	100 "	308	173	32 "	4.1 "	
9 in. cut-off, " " "	90 "	162	138	22 "	2.8 "	
6 " " " " "	85 "	135	134	22 "	2.8 "	

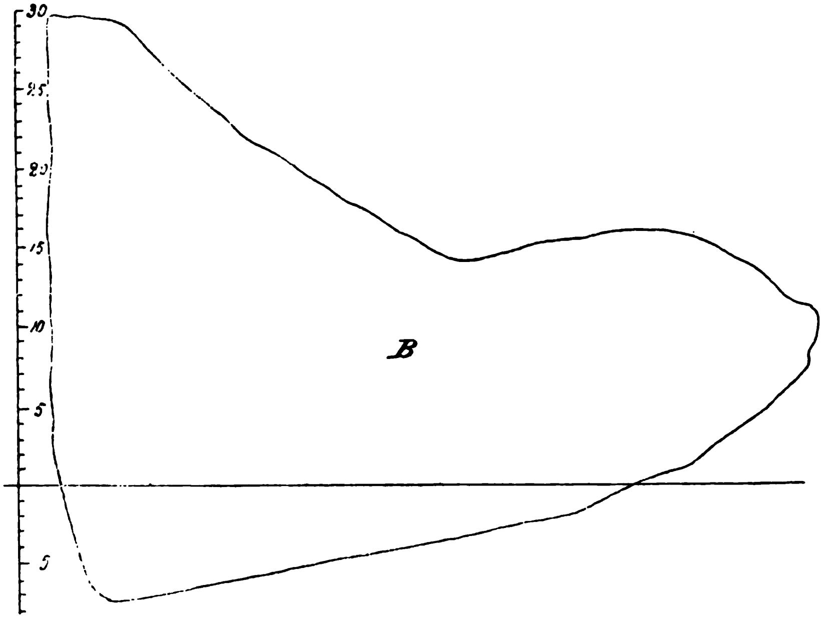
Samples of indicator cards are appended, A, B, C, and D, corresponding to the four conditions given above for the "Pomham," with the link in full gear. Cards E are for the same conditions as



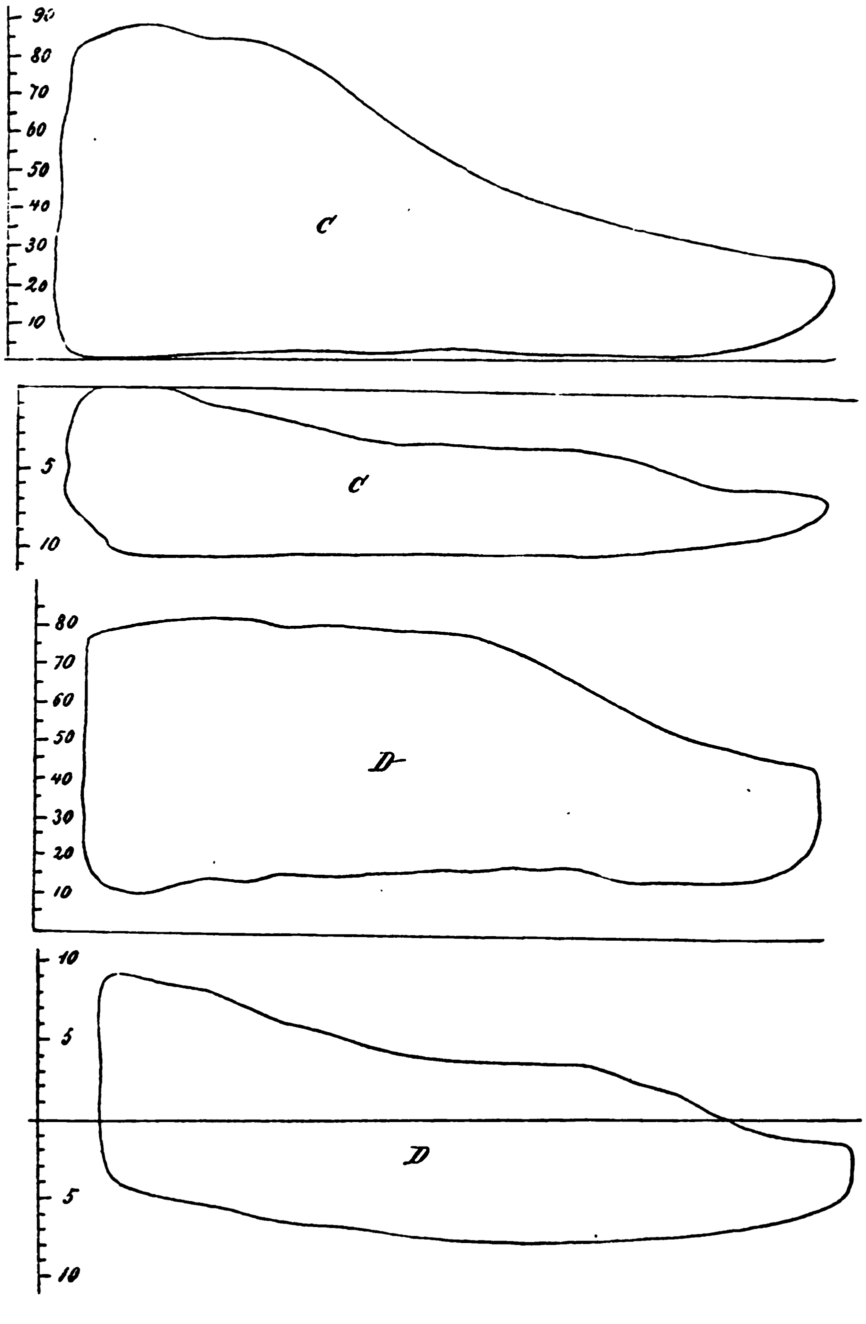


C, except that the link was set in half gear, thus causing more "cushion" in the low cylinder. Such increase of cushion resulted in a very sensible reduction of pounding or laboring of the low pis-





ton in passing the centre. The "Pomham" ran more smoothly at 9-inch cut-off than at "following full," but at 6-inch cut-off the action was not satisfactory regarding smoothness of running. The


90
80
70
60
50
40
30
20
10
C
5
10
C
80
70
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D
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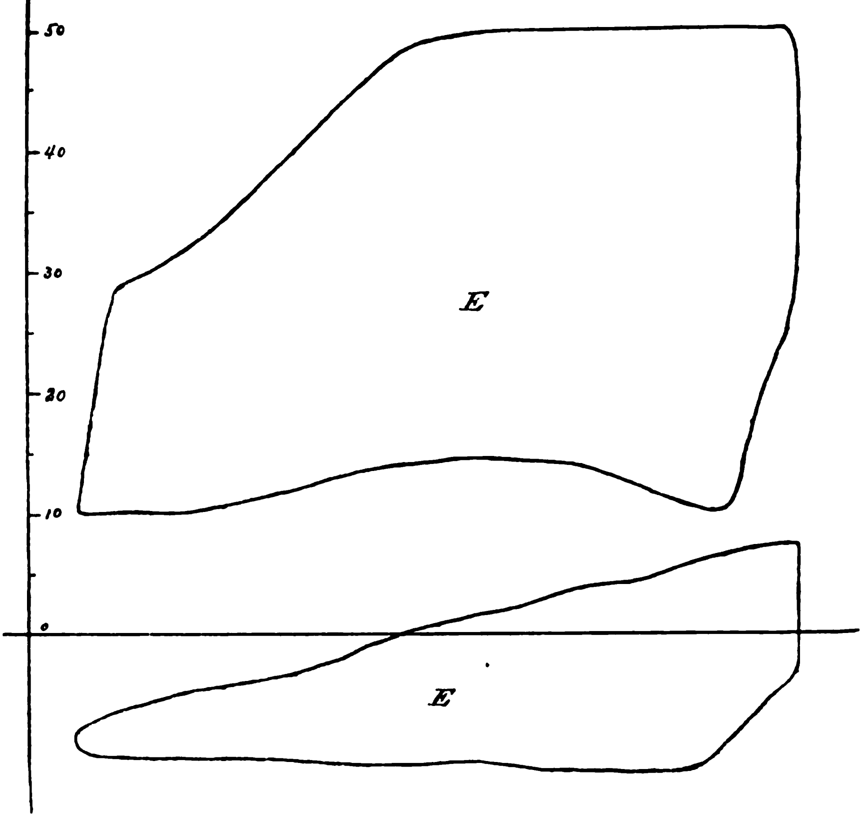
10

"Squantum," however, worked as smoothly at 6-inch cut-off as at 9 inches.

The water consumption compares favorably with the best results yet recorded for marine engines of similar type. For example, the best results for compound engines of the Committee on Marine Trials of the British Society of Mechanical Engineers are for the engines of the steamship "Fusi Yama," having 350 horse-



power compound unjacketed cylinders, the water consumption per hour per horse-power being 21.17 pounds, and the coal consumption 2.66 pounds for half cut-off, or five expansions. This includes, however, the consumption of both the main engines and pumps. Five expansions correspond to 9 inches cut-off in the table, (page 305). The indicator cards marked E are those of the "Fusi Yama."

SPEED TRIALS.

These were made over a measured 1-knot course, in 6½ fathoms of water, and resulted as shown in the table on page 310.

GENERAL CONCLUSIONS AND RECOMMENDATIONS.

1. The economy of the engines is equal to the probable average of their class. Practically the same economy is obtained by cutting off at half stroke in high cylinder as at the shorter cut-off of one third.

It is probable that there was too much miscellaneous leakage of steam, and investigation should be made to determine if this loss can be reduced.

2. The economy of the boilers is low, but it is not probable that the evaporation per *dollar's* worth of coal can be increased, the price of the latter being very low.

3. The smoothest action of the engine results from carrying the links at half gear, thereby increasing the "cushion" in the low cylinder.

4. The only means of setting the cut-off being by a screw, the engineers prefer to run "following full stroke," because of the frequent stops to be made, each of which requires the engine to be worked a short time without cut-off. The engines are, therefore, worked most of the time at about 40 per cent. greater steam consumption than would be the case if the constant use of half cut-off was insisted upon. A quick and easy link movement for setting the cut-off would, therefore, be a valuable improvement.

5. The amount of power expended to maintain a speed of eleven statute miles in still water is consistent with proper hull design, efficiency of mechanism, and propeller action. At higher speeds the power required is excessive, as naturally it should be, for such small vessels.

TESTS OF SPEED.

DATA	"POMHAM."*				"SQUANTUM."*	
	At Ordinary Boiler Pressure.		At Special Boiler Pressure.		At Special Boiler Pressure.	
Data	1st Run. May 22, 1890.	2d Run. May 22, 1890.	1st Run. May 22, 1890.	2d Run. May 22, 1890.	1st Run. May 23, 1890.	2d Run. May 23, 1890.
Time	11.34.0 to 11.39.55 A.M.	11.45.0 to 11.57.50 A.M.	12.6.55 to 12.11.45 P. M.	12.30.15 to 12.35.50 P. M.	2.42.32 to 2.47.57 P. M.	3.02.26 to 3.07.40 P. M.
Boiler pressure	85	85	110–110	105–98	110–88	115–95
Horse-power	150	150	320	318	305	310
Revolutions per minute	131	137	181	179	168	174
Speed in knots per hour	10.51 With tide.	8.8 Against tide.	12.10 With tide.	10.71 Against tide.	11.08 With tide.	11.43 Against tide.
Speed in statute miles per hour	12.08 With tide.	10.12 Against tide.	14.26 With tide.	10.71 Against tide	12.75 With tide.	13.19 Against tide.
Tide in statute miles per hour	0.98	0.98	0.98	0.98	0	*0
Still-water speed, statute miles per hour	†11.10	11.10	13.28	13.28	12.98 At average of 171 revolutions.	12.98
Speed by log in statute miles per hour for still-water	12.08	12.62	14.26	13.3	13.98	13.73
Error of log	†0.98	†1.52	†0.98	†0.92	†1.00	0.75

Both boats had been recently docked and cleaned. * As the revolutions differ with and against the tide, the latter is not represented by the difference of above run; the tide determined by drifting was found to be practically nil. † The slip of the screw was 13 per cent.

TECHNICAL INSTRUCTORS IN TECHNICAL SCHOOLS.

BY PRESIDENT HENRY MORTON.

DURING a recent conversation with Mr James Dredge, C. E., the editor and proprietor of the English Journal *Engineering*, which is, I suppose, without question the leading journal of the world in its department, the subject of technical instruction in technical schools naturally came up, and as the views expressed by Mr. Dredge so exactly accorded with those which have been held and acted upon by those directing the policy of the Stevens Institute of Technology, I feel that I ought to make record of them in this place.

Writing simply from memory, and making no attempt to express more than the general ideas conveyed by Mr. Dredge's remarks, I would say that, in substance, he stated as follows:

The great trouble with the technical instruction furnished by the instructors in technical schools is its lack of practicality.

As a rule, such instructors have little or no direct contact with the engineering work of the day going on around them, and as a result they soon fall behind the rapid advance of the art or profession, and teach in a routine manner much which is obsolete.

An ideal instructor in these subjects would be a man who, while versed in mathematics and in the theory of the profession, yet also came to his work of instruction fresh from the practice of the shops.

Speaking of "theory," by the way, that is a word usually misunderstood when applied to technical science.

It here means not some deductions from a limited experience which attempt to forecast the unknown results of new combinations, but the systematic classification of past experience, or the concrete condensation of all past knowledge, logically expressed.

The true master of theoretical mechanics is not the man who attempts to apply a few facts and formulæ to a widely extended field of results; but is the man who, having explored the vast field of previous experience, and classified and properly correlated all the facts therein developed, is prepared to apply to a new case the rules and methods which a multitude of past experiences have demonstrated to be the best.

To remarks substantially like the above I replied :

In view of what you have just said you will probably be interested in the following statement :

About the time (20 years ago) when the Stevens Institute of Technology was first organized, the Trustees of another college of long standing and high repute passed resolutions increasing the salaries of their professors, but at the same time requiring that they should do no work outside of that called for in their courses of instruction.

This action was considered by the authorities of the Stevens Institute of Technology, and was so far from being approved that steps were taken leading to the establishment of a Department of Tests, in which work of all sorts, from the testing of steam engines and boilers, water wheels, gas works, gas engines, the strength of iron, steel, and various alloys, and the like, to the analysis of waters, oils, and commercial materials generally, was undertaken, and distributed among the various members of the Faculty, according to its relations to the various departments.

This Department of Tests has continued in active operation to the present day, and has enabled us to contribute to Engineering Science a number of original researches, such as those on The Economy of Steam Engines as Influenced by wide Variations of Speed. New Methods of Discrimination between and new Proper-

ties of Lubricants. Determination of Latent-heat of Ammonia, and Efficiency of this Liquid on a Practical Scale in large Refrigerating Machines. The Efficiency of Water-gas as a Steam Boiler Fuel. Determination of Maximum Economy yet reached in Pumping Engines (at Pawtucket). Relative Efficiency of a Screw Propeller when Pushing and Pulling a Boat respectively, as Applied to Ferry-boats of 700 Tons.

So far from interfering with or impairing the efficiency of those concerned, in their duties as instructors, this work has been of incalculable value in vitalizing their teaching and keeping it abreast of the practical developments of the day.

In reference to the above statements, Mr. Dredge expressed his approval in emphatic terms.

In this connection I would remark, that the benefit conferred upon the public at large by an institution like our Department of Tests, where matters of all sorts can be ably and impartially investigated without bias or influence of any kind, and with the one aim of discovering the facts, is an immense one.

As a matter of fact, the work of our Department of Tests has, in numberless cases, resulted in the exposure of errors and fallacies in machines and processes examined, which were in a fair way of involving those interested in large financial losses.

The exposure of such errors and fallacies is, however, not always appreciated at its true worth by all concerned, and remarks have been repeated to me which have evidently come from those who thought that a favorable report was an article of commerce, and have been disappointed to find that such was not the case, as far as our Department of Tests was concerned.

RELATIVE MERITS OF VARIOUS STEAM TABLES.*

BY PROF. D. S. JACOBUS.

IN discussing the Report of Duty Trials of Pumping Engines, submitted to the American Society of Mechanical Engineers by a committee of which Mr. George H. Barrus was the Chairman, the writer examined the various steam tables now in use, and presented the following matter regarding their relative accuracy, which it is thought may be of sufficient interest to warrant republication here.

First.—The steam tables in general use give Regnault's values for the pressures corresponding to given temperatures, and for the total and latent heats of evaporation, with all the accuracy necessary for practical work.

Second.—The tables differ slightly in the values of the density of the vapor, which in some cases are derived from the experiments of Fairbairn and Tate, and in others by means of the thermo-dynamic relations that exist between the temperatures and corresponding pressures and latent heats, determined by Regnault.

Third.—The greatest difference between the density of steam at ordinary pressures, derived by Fairbairn's experimental formulæ and by thermo-dynamic laws, is about 3 per cent.

Fourth.—The results obtained by thermo-dynamic laws are probably the most reliable.

Fifth.—In special cases where scientific accuracy is required it would be more logical to use the densities derived by thermo-

* Abstracted from matter presented at the Richmond meeting of the rican Society of Mechanical Engineers, November, 1890.

TABLE I.

COMPARISON OF QUANTITIES GIVEN IN VARIOUS TABLES OF THE PROPERTIES OF SATURATED STEAM.

Temperature of Ebulition by Air Thermometer.		Absolute Pressure.						Latent Heat in B. T. U. per Pound.					Total Heat above 32° Fahr. in B. T. U. per pound.					Volume of One Pound in Cubic Feet.						
Degrees Centigrade.	Degrees Fahrenheit.	* Regnault.		† Porter.	‡ Clark.	| Dery.	¶¶ Peabody.	¶ Regnault.	† Porter.	‡ Clark.	| Dery.	¶¶ Peabody.	¶ Regnault.	† Porter.	‡ Clark.	| Dery.	¶¶ Peabody.	** Rankine.	†† Clausius	‡‡ Fairbairn.	| Dery.	† Porter.	‡ Clark.	¶¶ Peabody.
		Atmos.	lbs. p. sq. in.	lbs. p. sq. in.	lbs. p. sq. in.	lbs. p. sq. in.	lbs. p. sq. in.																	
100	212	1	14.7	14.7	14.7	14.7	14.7	965.7	965.7	965 2	965.7	965.8	1146.6	1146.6	1146.1	1146.6	1146.6	26.36	26.36	26.29	26.38	26.34	26.36	26.60
130	266	2.671	39.26	39.26	39.13	39.26	39.26	927.2	927.3	927.0	927.3	927.9	1163.0	1163.1	1162.6	1163.1	1163.1	10.48	10.46	10.24	10.47	10.24	10.48	10.55
160	320	6.120	89.96	89.95	89.76	89.95	89.95	888.5	888.4	888.6	888.4	889 5	1179.5	1179.5	1179.0	1179.5	1179.5	4.82	4.80	4 72	4.81	4 72	4.80	4.86
190	374	12.425	182.65	182 59	182.30	182.60	182.27	848.9	840.0	850 5	849.0	819 5	1195.9	1196.0	1195.4	1196.1	1196 0	2.48	2.47	2.54	2.48	2 54	2.46	2 50

* Experiences par M. V. Regnault, vol. i, p. 624.
† The Richards Steam Engine Indicator, by C. T. Porter, pp. 66 to 74.
‡ Manual of Rules, Tables and Data for Mechanical Engineers, by D. K. Clark, pp. 387 to 390.
| Transactions of the American Society of Mechanical Engineers, vol. xi, pp. 101 to 105.
¶ Experiences par M V. Regnault, vol. 1, p. 748.
** Rankine's Steam Engine, pp 592 to 596.
†† Article by Thomas Rowe Edmunds, published in "The Philosophical Magazine and Journal of Science," vol. xxx, fourth series, 1865, p. 10.
‡‡ Mills and Millwork, Fairbairn, pp. 212 to 214.
¶¶ Tables of the Properties of Saturated Steam and Other Vapors, by Cecil H. Peabody, pp. 26 to 30.

dynamic laws, as given in the tables of Rankine and Clausius or as transformed by M. V. Dwelshauvers-Dery, than the experimental densities given in Porter's tables. For all practical purposes, however, the experimental densities are sufficiently accurate.

In Mr. Porter's table, which has been included in the report on the Duty Trials of Pumping Engines, the experimental densities are employed for pressures above that of the atmosphere, and the theoretical densities for pressures lower than the atmosphere. The difference in the values of the density, as given in Porter's tables, and as determined by the thermo-dynamic formulæ, is about 2 per cent. for pressures in the neighborhood of 60 pounds absolute per square inch. Above this point the difference decreases until the absolute pressure is about 125 lbs. per square inch, at which point the two values are the same. Above 125 lbs. per square inch the values differ in a reverse way from that which occurs between the pressure of the atmosphere and 125 lbs. At 210 lbs. absolute pressure, which is the highest figure given in the table, the difference is about 4 per cent. Mr. Porter's transformations of Regnault's work are extremely accurate, and this portion of his table is more elaborate than the corresponding quantities in any other table now published. D. K. Clark's table contains slight discrepancies in the transformation of Regnault's work, which, however, are too small to affect any practical problem.

The experiments of Fairbairn and Tate cover a range of from only about 3 to 56 lbs. per square inch absolute pressure, and consequently it is illogical to employ the empirical formula, proposed by Mr. Fairbairn, which fits this range for much higher pressures. To obtain the figures given in Mr. Porter's tables, Fairbairn's formula must be employed for steam at pressures three or four times as great as those at which the formula is known to give results that agree with experiments.

This, however, is not an argument against the accuracy of the results given in Mr. Porter's tables for pressures up to 125 lbs.

per square inch, because at this point the experimental agrees with the thermo-dynamic equation. Above 125 lbs., however, the density by Fairbairn's formula varies in the opposite way from which it did at the lower pressures, and at very high pressures the results are considerably in error.

No comparison is herein presented for pressures below that of the atmosphere, because the values over this range are the same in all the tables, the pressures and the total and latent heats being those derived from Regnault's experiments, and the volumes those given by thermo-dynamic relations.

COMPARISON OF THE THEORY WITH THE EXPERIMENTS OF MESSRS. FAIRBAIRN AND TATE.

No. of Experiment.	Temperature. Fahrenheit.	Volume of One Pound of Steam in Cubic Feet.		Difference.	Difference ÷ Exper. Vol.
		By Theory.	By Experiment.		
1	136°.77	132.20	132.60	−0.40	$-\frac{1}{330}$
2	155.33	85.10	85.44	−0.34	$-\frac{1}{250}$
3	159.36	77.64	78.86	−1.22	$-\frac{1}{65}$
4	170.92	60.16	59.62	+0.54	$+\frac{1}{110}$
5	171.48	59.43	59.51	−0.08	$-\frac{1}{744}$
6	174.92	55.18	55.07	+0.11	$+\frac{1}{501}$
7	182.30	47.28	48.87	−1.59	$-\frac{1}{30}$
8	188.30	41.81	42.03	−0.22	$-\frac{1}{191}$
9	198.78	33.94	34.43	−0.49	$-\frac{1}{70}$
1′	242.90	15.61	15.23	+0.12	$+\frac{1}{126}$
2′	244.82	14.77	14.55	+0.22	$+\frac{1}{66}$
3′	245.22	14.67	14.30	+0.37	$+\frac{1}{39}$
4′	255.50	12.39	12.17	+0.22	$+\frac{1}{55}$
5′	263.14	10.96	10.40	+0.56	$+\frac{1}{19}$
6′	267.21	10.29	10.18	+0.11	$+\frac{1}{93}$
7′	269.20	9.977	9.703	+0.274	$+\frac{1}{35}$
8′	274.76	9.158	9.361	−0.203	$-\frac{1}{47}$
9′	273.30	9.367	8.702	+0.665	$+\frac{1}{13}$
10′	279.42	8.539	8.249	+0.290	$+\frac{1}{28}$
11′	282.58	8.145	7.964	+0.181	$+\frac{1}{44}$
12′	287.25	7.603	7.340	+0.263	$+\frac{1}{28}$
13′	292.53	7.041	6.938	+0.103	$+\frac{1}{66}$
14′	288.25	7.494	7.201	+0.293	$+\frac{1}{24}$

Rankine compared the liability to error of the thermo-dynamic determination of the density, as derived from the latent heats and pressures observed by Regnault, and of the experimental densities determined by Fairbairn and Tate, and concluded that the difference between the results obtained by the two methods was greater than the probable error of the experimental quantities involved in the problem. He advanced the supposition that there may have been a difference in the molecular condition of the steam in the two sets of experiments, as the steam in Regnault's experiments was in motion, whereas that in Fairbairn's and Tate's experiments was at rest. The table on page 317 was prepared by Rankine in order to compare the results given by the two methods.*

OILS USED IN LUBRICATION.—THEIR CHEMICAL REACTIONS AND METHODS OF DETECTION IN MIXTURES.

BY PROF. THOS. B. STILLMAN.

(Continued from page 215.)

GIBBS' viscosimeter, Fig. 13 (George Gibbs, M. E., Chicago, Milwaukee and St. Paul Railroad), was designed to overcome some objectionable points in existing forms of viscosimeters.

The idea being: *First.*—To have a large body of hot oil as a bath surrounding the oil to be tested in order to keep the latter at a perfectly uniform temperature.

Second.—To apply a forced circulation to the bath by means of a double action pump, to insure equality of heat in all parts.

Third.—To deliver the oil to be tested at the orifice under a constant head, which is accomplished by means of a pneumatic trough.

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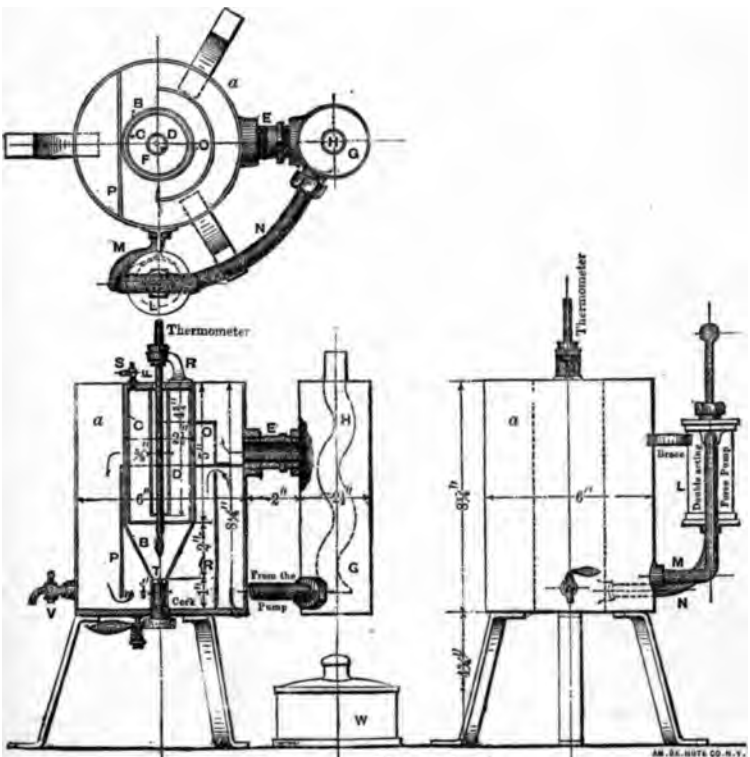
* "Miscellaneous Scientific Papers," by Professor Rankine, p. 423.

Fourth.—To supply convenient means for accurately measuring the temperature of the oil near its delivery point.

The large reservoir *a* is of copper, with heavy brazed bottom. This contains the cylindrical inside chamber with conical bottom *B*. At the lower end of this is the gauged aperture *T*. Inside of this chamber fits the inverted reservoir *C*, holding the oil to be tested. In the interior of this chamber is a tube *D* extending nearly to the



C. M. & ST. PAUL RY. CO.
(Motive Power Dept.)
GIBBS' VISCOSIMETER.

FIG. 13.

bottom of the same. This tube admits air to determine the head of the oil, and also to admit the thermometer *F*. The outside bath

a contains the deflector plates *O*, *P* and *R* to obtain proper mixing of the bath. The heating of the bath is done by a lamp *W*, set underneath the separate heating chamber *G*. The size of the orifice at *T* is $\frac{1}{16}$ inch.

The following table shows the results of viscosity tests upon various oils made with this instrument.

VISCOSITIES OF VALVE OILS AND STOCKS.

	Gravity.	Flash.	Per cent. Mineral Oil.	Viscosities. 250° F.	300° F.	350° F.	400° F.
Nat. Ref'g Co., Loco. Cyl	26.8	525°	75.7	38 sec.	32	26	.....
Nat. Ref'g Co., German	25.8	550	70.0	43	33	28	.....
Perfection valve oil	26.0	510	54.7	35	29	25	......
" " (another)	25.7	undet	65.0	34	28	24	......
" " "	25.9	510	undet	.....	......	23	21
Vacuum valve oil	25.2	535	95.0	......	......	27	23
C., M. & St. P. valve oil	26.4	485	66.7	......	......	23	21
Extra lard oil (average of 3 samples)	....	......	... ...	25	23	21	20
St'd Oil Co., No. 1 stock	27.0	520	100	46	32	26	22
" " 2 "	27.3	510	100	47	32	26	22
" " 3 "	27.8	490	100	39	30	25	21
" " 4 "	26.2	525	100	46	33	27	23

Viscosities expressed in seconds for 50c.c.

VISCOSITIES OF CAR AND ENGINE OILS.

	Gravity.	Flash.	Per cent. Mineral Oil.	Viscosities. 75° F.	110° F.	150° F.
National Ref'g Co., car oil	30.8	200°	100	223	68	41
Relief Oil Works, "	30.4	200	100	163	61	38
Galena car oil	28.5	160	90	102	54	36
" " "	28.2	165	90	83	50	33
" " "	28.7	155	90	102	54	36
" " "	27.8	170	90	88	52	34
" " "	26.3	285	91.9	234	99	49
" " "	26.5	260	91.0	257	98	48
Relief Oil Works, engine oil	30.1	210	100	130	64	37
National Ref'g Co., " "	26.5	385	100	740	113	54

Viscosities expressed in seconds for 50c.c.

The viscosities of a number of other oils, at the temperature of locomotive cylinders, as made by this instrument, are shown in the following chart of curves. (Fig. 14.)

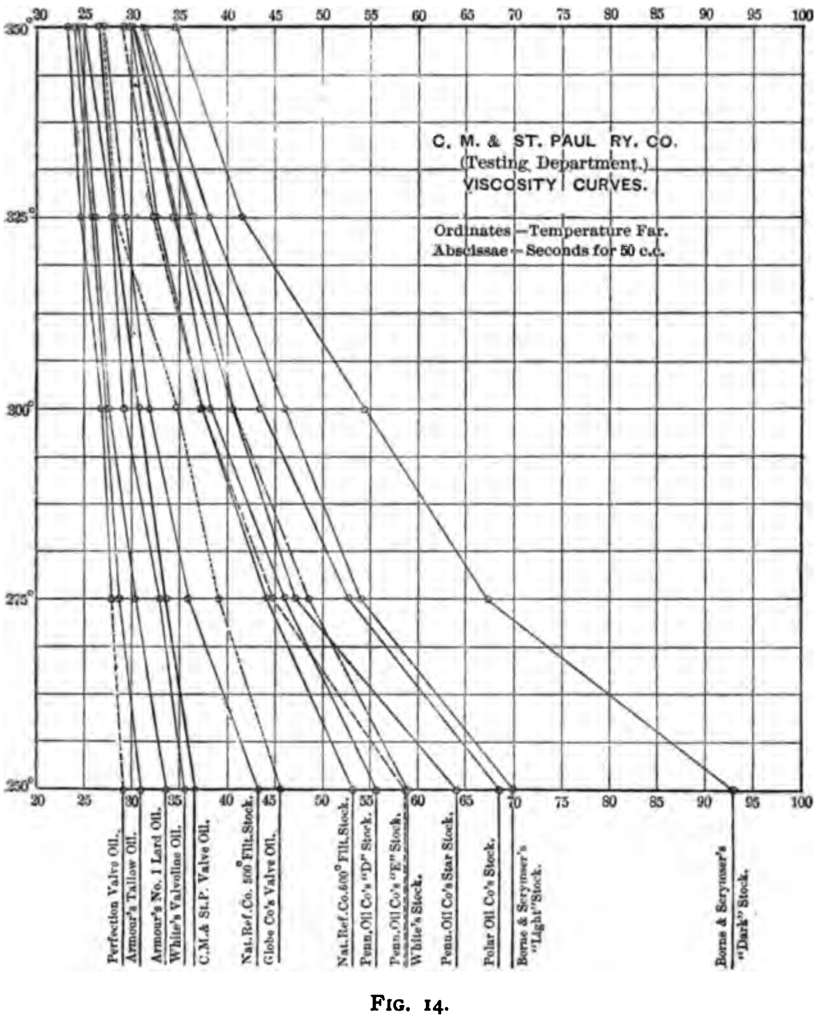


FIG. 14.

A viscosimeter on an entirely different principle than the others already described is the Perkins instrument (G. H. Perkins, Supt.

Atlantic Oil Refinery, Phila., Pa.) It consists of a cylindrical vessel of glass, surrounded by a proper heating vessel, and fitted with a piston.

This piston fits into the cylinder to within $\frac{1}{1000}$ of an inch.

In practice, the cylinder is filled nearly full with the oil to be tested and the piston inserted. The time required for the piston to sink a certain distance into the oil is taken as the measure of viscosity. A full description of the apparatus will be found in *Transactions of the American Society of Mechanical Engineers*, vol. ix., page 375.

J. Lew, (Ding. Polyt. Jour. 1891, p. 280), introduces an instrument not only for the viscosity but also to include the internal friction of an oil. By these means it is claimed the lubricating value of the oil is absolutely determined.

The author states that the internal and external frictional resistances are different, and vary in the different oils at various temperatures. Formulæ and methods are given by which co-efficients are determined and used in the examination of the lubricating value of oils.

Figure 15 represents the viscosimeter designed and used in my laboratory at the Stevens Institute of Technology.

It consists of a copper bath *B* surrounding the vessel *A*, also of copper, and which holds the oil whose viscosity is to be determined. The tube *f* is of copper, but at *e* it is joined to a glass tube, which is extended to *d*—this latter is used for measuring the oil, and is carefully graduated. Sizes and dimensions of the apparatus are given in the figure.

This apparatus was designed to overcome two difficulties usually occurring in the use of other viscosimeters—viz.: *First*, loss of heat in the oil during its passage from the containing vessel to the receiving flask; and *second*, to have the chamber *B* of size to work small quantities of oil. *First.*—When the viscosity of an oil is taken at the ordinary temperature the measurement of the oil in the receiving flask will correctly indicate the amount of oil deliv-

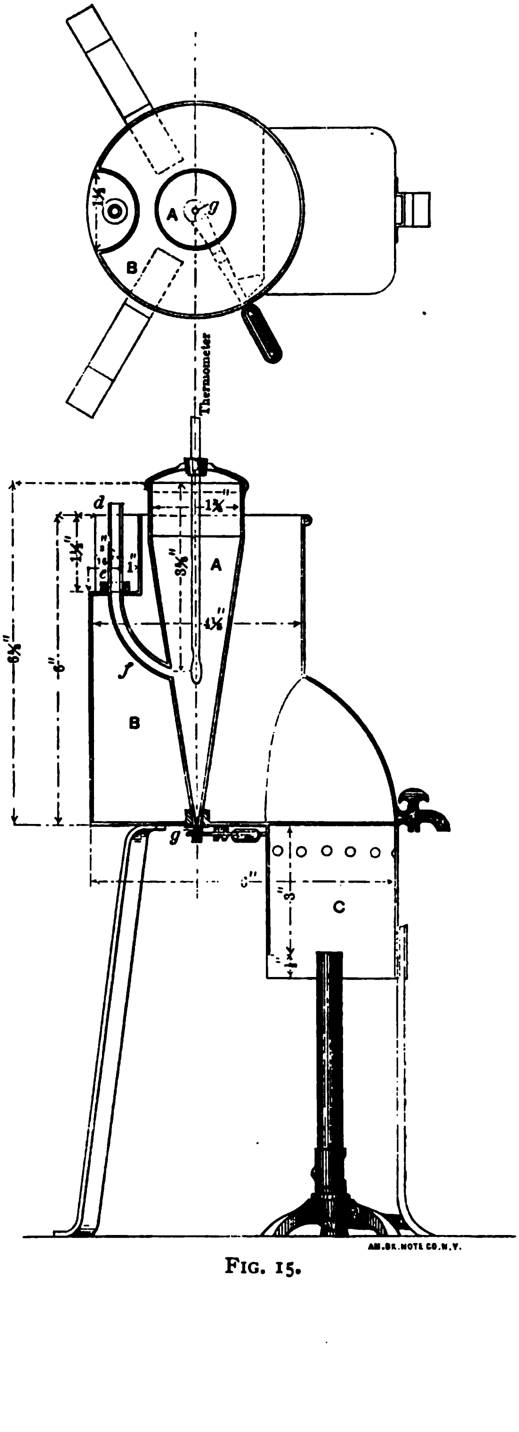


FIG. 15.

ered through the aperture. The conditions are altered, however, when high temperatures are required, since the oil in running in a fine stream through the orifice is chilled in contact with the air, and if its temperature be taken at the moment its volume is read in the receiving flask, a notable difference is indicated, depending upon the temperature of the room and of the oil before delivery.

In this instrument provision is made for reading the volume of the oil directly in the chamber A without any graduated receiving flask, as follows:

The tube *f e d*, is graduated so that when the oil in the vessel A is at the proper level, the oil also reaches the upper graduated mark upon the tube *d e*. The lower graduated mark upon the tube indicates when 25$^{c.c.}$ of the oil has been delivered from A through the orifice *g*.

This graduation is absolutely correct for the purpose, and shows accurately the viscosity of the oil at any temperature, as indicated by the thermometer in A.

None of the oil in tube from *e* to *d* passes into A during the delivery of the 25$^{c.c.}$ through *g*, since the tube *f e d* is only partially emptied of its oil; the level of the oil in A, after the delivery of the 25$^{c.c.}$ still remaining above the point where the tube *f* enters A.

Second.—Oftentimes the samples of oil sent for examination do not exceed 100$^{c.c.}$ in bulk, an amount entirely too small if other tests are to be included.

Many forms of viscosimeters require 100$^{c.c.}$ of oil for the viscosity test, and not a few 50$^{c.c.}$

I have found 25$^{c.c.}$ to be ample, provided the aperture at *g* is small enough to prevent a too rapid delivery of the oil and consequently render close readings and comparisons difficult. By making this orifice $\frac{3}{64}''$ sufficient time is secured to obtain accurate results.

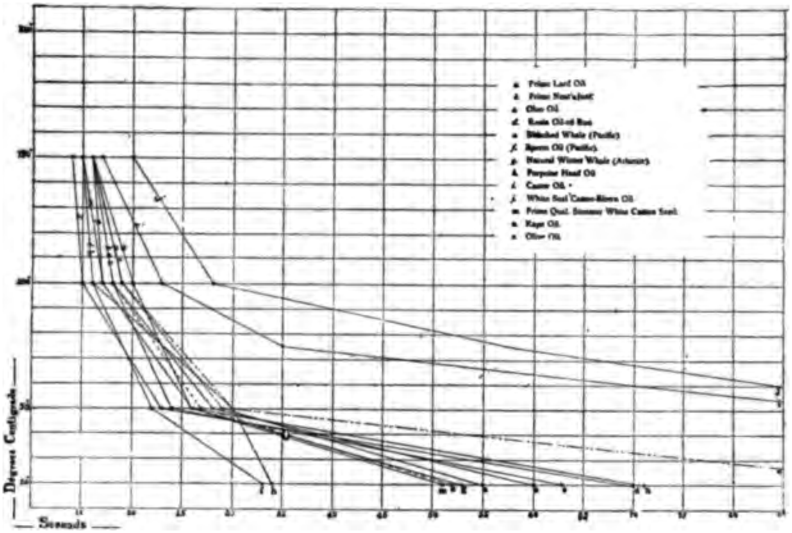
If the operator prefers not to use the graduated tube *f e d* to measure the oil, a receiving flask, properly marked, can be placed under *g*, as in other forms of viscosimeters.

The plan suggested by Schubler (see page 203), that viscosities should be comparable with water is the only proper one, and in the

following determinations of viscosity in my laboratory the comparison is included.

	Seconds at 20° C. = 68° F.	Seconds at 50° C. = 122° F.	Seconds at 100° C. = 212° F.	Seconds at 150° C. = 302° F.	Seconds at 200° C. = 392° F.
Water	15	....	....	....	
Prime lard oil	55	29	19	16	
No. 1 " "	70	30	18	16	
XXX " "	73	31	18	16	
Prime Neat's-foot oil	60	28	18	16	
White " " "	70	28	18	16	
Pure hoof oil	72	30	19	16	
Oleo oil	200	30	19	16	
Horse oil	64	35	17	16	
Gelatine oil	solid.	solid.	solid.	360	35
Rosin oil, 1st run	....	....	19	15	
" " 2d "	70	23	15	14	
" " 3d "	75	22	15	14	
Dog-fish oil (Pacific)	50	26	17	16	
Right whale oil (Pacific)	58	27	18	15	15
Natural bow head oil (Pacific)	47	27	18	16	
Bleached whale oil	52	27	18	16	
Natural winter Sperm oil (Pacific)	33	22	16	15	
Bleached oil (Pacific)	29	22	16	15	
Natural spring sperm oil	30	22	17	16	15
Bleached spring sperm oil	32	22	16	15	
Natural winter whale (Atlantic)	53	26	17	16	
Bleached " " "	43	26	18	15	
Extra bleached winter whale (Atlantic)	55	28	18	16	
Natural spring whale (Atlantic)	57	26	18	16	
Bleached spring whale	52	26	18	16	
Porpoise head oil	34	30	16	15	
Sea elephant oil	51	36	17	16	
Bank oil	39	30	17	16	
Prime crude Menhaden oil	39	24	17	16	
Brown strained " "	42	24	18	16	
Light " " "	40	24	17	16	
Natural winter Menhaden oil	41	25	17	16	
Bleached " " "	34	24	17	16	
Extra bleached winter white Menhaden oil	39	24	17	16	
Castor oil	73	95	23	17	15
"White seal" castor blown oil	....	185	28	20	20
Prime quality summer white cotton seed oil	51	26	17	15	
Prime quality winter white cotton seed oil	57	27	18	15	
Herring oil (Pacific)	56	26	18	16	
Rape oil	71	26	20	16	15
Olive oil	63	24	18	16	15

A chart of a few of the above oils are shown on the following page.



An examination of these tables and curves bring prominently forward the following facts:

That at high temperatures the variation in the viscosity of simple oils is very slight.

That "blown" oils, and "gelatine oils," which are manufactured especially to give "body" to compounded oils fail in their purpose at high temperatures.

This is shown especially in Fig. 16, by the curves of the compounded oils—gelatine oil, for instance—which at 20° C. remains solid, likewise at 50° C. and 100° C., but at 150° C. (302° Fahr.) it indicates a viscosity of 360 seconds, and at 200 C. a viscosity of 35 seconds.

This "gelatine" oil is generally a compound of aluminium oleate, lard and petroleum.

Castor oil shows the highest variation of any of the simple oils, while sperm oil shows the least, and it is probably this property of the latter that has given it the reputation as the standard oil in lubrication.

Of the animal oils, lard oil ranks first in lubrication, followed in order by neat's-foot, horse oil and tallow oil.

Generally speaking, the marine oils are the better lubricants, with the exception that acidity often rapidly forms in them, and so renders them valueless for the lubrication of many forms of machinery. The order of their value would be sperm oil, porpoise head oil, bleached Menhaden oil, whale oil, dog fish oil, sea elephant oil and herring oil. Of the vegetable oils, rape oil is the recognized standard in lubrication. Its use for this purpose is very limited in this country, though in Germany and Russia large amounts are annually consumed.

Olive oil, while a good lubricant, is too high in price and its place has been taken in later years by refined cotton-seed oil. This latter oil, while seldom used alone in lubrication, is added to lard oil in proportions varying from 20 to 50 per cent., producing a mixture that lubricates nearly as well as pure lard oil, though acidity more rapidly develops than in lard oil alone. Castor oil is largely added to other oils to give high viscosity at ordinary temperatures, and to produce "body," which it loses at high temperatures. Its use for this purpose still continues in England, while in this country "gelatine" oil has largely taken its place, and produces a more viscid oil at less expense.

The so-called "seal castors" and "blown oils" are made from cotton-seed oil, and are used in place of "gelatine" oil to produce high viscosity, at a much lower cost than "gelatine" oil.

The compounded oils, as now made for lubrication, show that the manufacturer considers the best selling oil to be one which has a high viscosity at ordinary temperatures, and that in the majority of cases this property has been added to the oil by use of thickening compounds.

Consult the following:

Die Untersuchungen der Schmieröle und Fette, by H. Gusenheimer; Journal Anal. Chem., Vol. I., p. 150; Analyse der Fette and Wachsarten, Benedict, p. 45; Dingler Polyt. Journal, 261, p. 81; 259, p. 270; 260, p. 282; 261, p. 311; Portefeulle Economique de Machines, 1886, Vol. II., p. 206; Berichte, Vol. 267, p. 592; Mitth. der Tech. Versuchsanstalten, 1888, Vol. III., p. 8; Ding. Polyt. Jour., 279, p. 113; Journal Society Chem. Industry, Vol. X., p. 617; Chem. Zeitung, 1891, p. 298; Oils and Varnishes, Cameron, p. 303; Zeitschrift für Anal. Chem., XX., 465; Zeitschrift des Vereins Deutscher Ingenieure, XXXI., p. 251.

THE PURIFICATION OF WATER.

THE address delivered by Professor Leeds before the Chamber of Commerce of Rochester, N. Y., May 12, 1891, of which mention was made in the July INDICATOR, is given in part herewith :

Comparing the composition of the waters obtained on the 2d of May, at noon, from the Genesee River at Elmwood Avenue Bridge, and that from the conduit at Mount Hope reservoir, Professor Leeds stated that the water from the Genesee River had a slight yellow color, due to peaty matters in solution, and was slightly turbid. It had a flat taste and a slight odor. That from the Mount Hope reservoir was colorless, but manifested a whitish turbidity; it was pleasant to the taste and had no odor. The Genesee water contained .044 of a grain of free ammonia per gallon; the Hemlock, .032. The Genesee water contained of albuminoid ammonia, with organic nitrogen, .071 of a grain; the Hemlock, .078, slightly more. The Genesee water required to oxidize the organic matter, .147 of a grain of oxygen; the Hemlock Lake, .136 of a grain, or something less. The difference was due to these peaty organic matters in solution, which require a slightly greater amount of oxygen to oxidize them. The hardness of the Genesee water was 6.85 grains; the Hemlock Lake, 3.2. The total solids in solution in the Genesee water were 16.47 grains; in the Hemlock Lake, 5.08 grains. A count of the bacteria contained in the waters showed that there was in the Genesee River water 112 colonies of bacteria to the cubic centimetre; in the Hemlock Lake, 63 colonies. The samples were sent to me in jugs labeled 1 and 2, and at the time of making the analysis I did not know to which samples the numbers referred. The analysis showed that No. 1, the harder water, of course, came from the river. And I shall now label these bottles containing a portion of that water. And, in the first place, there is the Genesee water. Mr. President, you will notice this limpid matter in it. Perhaps you can see it.

After making the analysis, for reasons which I will explain presently, I added to each water a grain of sulphate of alumina,

and then filtered the samples through sand. This marked No. 1 is the filtered Genesee water; 2, the filtered Hemlock. I do not think that it is possible to notice any difference. Both of those samples are as entirely limpid, entirely colorless, as the purest distilled water that I could make in my laboratory. They are absolutely devoid of any color and any odor. The whitish opalescence, or the whitish turbidity, has been removed from the Hemlock water; the yellow, from the Genesee water.

This brings me to the treatment of waters by filtration. And at the outset I would like to say that I know of no method by which it is possible to render waters organically pure except by filtering; and, in the second place, I know of no practical method of bringing about that result except by the American system of mechanical filtration and purification. As these statements appear strong and unqualified, I think it is important that I should briefly review the history of our knowledge and practice during the course of the past ten years, in relation to this subject.

Some six years ago there was, I think, but one city in the United States which attempted to filter its water, and that was Poughkeepsie on the Hudson. At the present day there are more than one hundred, and the practice is increasing very rapidly. In England, and on the continent of Europe, the practice of filtration is well nigh universal. Some five years ago Jersey City and Newark, in New Jersey, requested me to visit the various water supplies, in England more especially, to study this matter of filtration of their waters, and I found that all the great cities, with the exception of Glasgow, filtered their water supplies. The most conspicuous example is London, with its population of five and a-half million of people. Its water supply is almost entirely taken from the River Thames, and that river receives the drainage of a very great population. The towns are compelled, by act of Parliament to purify their sewage to a certain point, but a great deal of filth finds its way into the Thames. By act of Parliament the several water companies that supply London are compelled to filter their water; and to effect that object they have filter basins which cover more than a hundred acres in area. Their method of filtration is to run the water into large reservoirs containing sand. The sand that does the filtering is about two feet in depth, and supported on a substratum of coarse stone. As the filth is removed it accumulates in a thin layer upon the top of the sand; and when the water—which

filters only under the pressure of the four feet, or thereabouts, of water standing in the reservoir—filters too slowly, they are compelled to send a force of men into the filter basin, shovel off the top layer of sand and dirt, remove it, wash it, and restore it to the filter bed. The same plan is followed at Berlin and other great cities on the continent.

HOW THE FILTER BEDS DO THEIR WORK.

It is easy to see how they remove the dirt, the gravel and the suspended matter; but how do these shallow basins of sand remove the living organisms—those organisms with which you are all so familiar under the name of bacteria; those organisms which, when they produce typhoid and other fevers, are known as disease germs? That operation was a complete mystery until the last four or five years. But few people had ever seen or examined bacteria before that period. It is entirely a new topic in this country; and the method by which they were removed from the waters was a profound mystery. It now has been shown that the bacteria remove the bacteria. The bacteria in the waters are comparatively few of a dangerous character; the great bulk of them are our greatest friends. It is through their aid, together with the oxygen of the air, that the filth in the water is destroyed. They feed upon it and they feed upon each other. Since that knowledge has been obtained, the object now is to cultivate the bacteria. In order to make the filter bed do its work effectively, it is necessary that the growth of the bacteria shall be facilitated until a filter bed becomes populated with an incredible number of millions of them. As the result of their activity they multiply themselves in vast numbers; and they form, at the top of the filter beds and between particles of sand, a sort of jelly or slime—a bacteria jelly; and it is by the aid of this bacteria jelly that the bacteria in the unfiltered water are removed. The bacteria come down into the pores of the filter, when they are caught by this jelly and they are consumed. And if the rate of movement of the water is slow enough it is possible to begin with water like that of the River Spree, which is a portion of the water supply of Berlin, containing 100,000 of bacteria to the cubic centimetre, and after passing through one of the filter beds the water which comes out will contain but forty or fifty bacteria. This takes place when the rate of filtration is such that 1,000,000 gallons of water pass through those filter beds per acre in twenty-four hours. If the rate

is diminished until only 300,000 gallons pass through in that interval, the bacteria can be diminished until there are only five or ten per cubic centimetre. But this rate is too slow to permit of economical use of the filter beds, and the consequence is that the authorities of Berlin require that the water shall pass through the filter beds at the rate of a million gallons per acre in twenty-four hours. The interesting fact is thus brought out that some of the foulest water, most polluted with sewage, is so filtered at the present day in the capital of Germany; the filtered water is submitted to the most searching criticism of Professor Koch, whose institute of hygiene is there, and to whose labor our knowledge on this subject is mostly due, and that this foulest of water is there taken, filtered, and then becomes the water supply of Berlin. If we can do as well or better than that, we have every reason to be satisfied that we are on the side of safety.

The foreign filter beds, excellent as they are, have never been introduced practically in the United States. Moreover, there is no prospect that they will be. The amount of water filtered per acre is so small that the first cost is a large one. In the second place, the climate of Europe and of England is altogether different from the climate of America. Those filter beds freeze up, even at London, and the engineers are sometimes greatly troubled. In the next place, in England, even in that temperate climate, a great quantity of algæ develop in the filter beds. In the United States, with our severe winters and the great trouble you have experienced in Hemlock Lake, from the growth of algæ, engineers are unwilling to undertake such method of filtration. This being the case, the attention of engineers has been directed to find some way of effecting a result which will satisfy our own needs. And the system that I shall bring to your notice in reference to your immediate wants is this American system.

The filter is simply a case made of boiler iron, of five feet, ten feet, or twenty feet in diameter, made strong enough to stand any pressure to which it is subjected. It contains a bed of sand three and one-half or four feet in depth. The water is passed through the filter under pressure and passes out of the bottom by a series of valves so constructed that they permit the water to pass, but entirely detain the sand. After a time, when the filth accumulates on the surface and through the bed of the sand, the operation is reversed, a current of filtered water under pressure is sent up from

below, the sand is washed, and the impurities pass out from a waste pipe, and then filtration is resumed. In practice, after filtering for ten hours, a filter operating on such water as the Genesee River can be purified by washing in ten minutes' time.

That it is possible by such a method to renovate the sand and dirt you will probably have no difficulty in admitting; but what will such a filter do with reference to the bacteria? If it is necessary to pass water at so slow a rate where the pressure is as light as that given by a head of four feet as is the case in the foreign filter bed, how is it possible to pass the vastly greater quantity through one of these American filters. One of these filters of which I have been speaking, ten feet in diameter, under a pressure of fifteen lbs. to the square inch, will filter successfully a quarter of a million of gallons per diem. In order to effect that result it is necessary to have something which will take the place of the bacteria jelly that I have described. And the most successful substitute is a jelly made of hydrate of alumina. It is obtained in this way: All natural water contains in solution carbonate of lime, to which its hardness is due. When sulphate of alumina is introduced into the water it is decomposed by the carbonate of lime, and sulphate of alum is formed and hydrate of alumina is set free. It is a perfectly white translucent jelly. It forms on the surface of the filter bed in contact with the grains of sand, and when the smallest particle of silt or the bacteria come in contact with it they are caught by it and held. It is possible to entirely remove the bacteria from water by use of this jelly. These filters worked in that manner have been repeatedly tested, and that point has been most carefully established.

The water that I have sent around the audience this evening is filtered water. It contains no bacteria. They were removed at the same time that the turbidity and the color were taken out. The question then is, whether the bacteria are to be removed by a bacteria jelly or by means of an alumina jelly. There are some who think that no chemical substitute whatsoever can rightly be employed in the purification of water. It appears to me to adopt such a sentiment is to renounce the advantages which the very elaborate study of this question has given to us. They say that hydrate of alumina, which is one-fourth of alum, is very pernicious to health. If alum ever went into your water supply I would concede the point that it is not a proper thing to use; but it does not go into the filtered water. The alum is so perfectly decomposed

that I never have been able to find it in the filtered water. The hydrate of alumina is left behind, and the alumina which goes into your water in a minute amount is also present in natural water itself. If you examine the analysis of the river water you will find that the water contains naturally some alumina. It is the alumina in the soil which makes spring water so bright. It is the alumina in the soil which makes the water of driven wells, filtered water. All that is proposed in this method is to take advantage of nature's methods.

In the sample that is before you a quarter of a grain of alum has been used. That is so small an amount that it is difficult to weigh it upon a druggist's balance. Of that quarter of a grain of alum, only one-third is alumina; and one-twelfth of a grain of alumina, or the $\frac{1}{100000}$th part of the weight of a gallon of water, is sufficient to remove all the dirt and all the bacteria by this process of filtration. The quantity is practically infinitesimal.

Unfortunately, the Genesee water, at the time it was sent to me, was in a very favorable condition. I wish it had been at its worst, because the difference is too slight to show what the process is capable of doing. This method is now in use supplying filtered water in much larger quantities than what you desire to have here. The City of Chattanooga, some four years ago, began taking some three million gallons of water from the Tennessee River. It has now gone on increasing its filtering plant, until it takes six million gallons, and it is all treated by the method I have spoken of. I have here a sample of water taken from the Wabash River at Terre Haute. It is not possible that the Genesee River should ever have water of the charaeter that you see here. It is loaded with mud. The water was so bad that I at first thought, when this sample was submitted to me, that it was a hopeless case. I am interested in this question, as a consulting chemist, from the fact that a great many waters are submitted to me by the people that are engaged in doing this work, and I am desirous of seeing this American system introduced generally. I think it will be universal before many years have passed. And here is one of the samples that was submitted. A plant was put in some year and a half ago to filter this Terre Haute water. The impurities were so great that I said that they could not be successfully handled without using as much as four grains of alum to the gallon. They have been filtering not three, but four and one-half million gallons of water with a three-million-gallon filter

plant. And this has been done with two grains of alum to the gallon, and less. The superintendents have been careful not to use more than that, because of the expense. They use less. And this is the largest amount of alum I have ever known to be used practically in the filtration of water.

I will not detain you longer than by saying I have here a working drawing, showing ten of these vertical filters, ten feet in diameter, which are doing this work at Terra Haute. The water is filtered under a pressure of two hundred pounds, and the filtered water is used for fire purposes as well as for general supply.

Here is the working drawing of a plant at a place in Kansas: a smaller plant. It is the same size as that at Bordentown, in New Jersey, Long Branch has for the past three years filtered and treated all its water in that way. It was much more deeply colored with peat than the Genesee River water was that came to me, or, it is possible for the Genesee ever to be colored. It came from a Cypress swamp. And the filtered water at Long Branch is colorless. And when the health inspector of Providence examined that plant he found that the filtered water contained two bacteria per cubic centimetre, while the unfiltered water contained three hundred.

In conclusion, then, I will say that this method is in use in one hundred of our American towns; that those who are using it are extending their plants to supply the increased demand; that by its use in the filtered samples which I have shown you, the organic nitrogen in the Genesee water was cut down to one-half the amount usually present, and also the water in the Hemlock Lake was cut down by the same amount. The Hemlock water, if filtered by this method, would be 100 per cent. purer than delivered to you as it is, and you consider it, as it is, very excellent water.

At the recent convention of the engineers in Philadelphia the expression of opinion was general that this method of treatment of waters was, in the near future, to be generally adopted. When the city of Liverpool put in its new water supply from Vrnywy Lake, the purest water they could obtain in Wales, they put on the descending main a filter plant; and I said to the chief engineer at Liverpool: "Why do you filter this beautiful mountain water?" and he said to me, "The public opinion in England is so strong in this matter that we cannot supply water unless it is filtered." If you have examined one of those filter systems you will find that all of the filtered water is passed through a well, at the bottom of which there

is a pavement of white porcelain, and the engineer and the people are not satisfied without, on looking through a depth of five feet of water, the filtered water should always go over that porcelain and be absolutely colorless. I think the time has gone by in this country when people will be satisfied with taking any water supply without they are made certain of its purity. As I said before, I know of no method of guaranteeing the purity of water except by filtration.

Mr. President, I trust I have been not too lengthy, I wished to answer the question which was asked: "If a temporary supply of 3,000,000 gallons of water is taken from the Genesee River can it be made colorless, can it be made pure from a sanitary standpoint?", I have answered that it can be, and that the method is one in large use, and is a method requiring so moderate an outlay that it has become feasible for the water supply of cities demanding a great amount of water.

BIBLIOGRAPHY OF Π.

BY PROF. H. A. WOOD OF THE STEVENS SCHOOL.

CYCLOMETRY is the science of circle measuring. Its two famous problems have been to find a straight line equal to the circumference of a given circle, and to construct a square equivalent to a given circle. These problems have engaged the attention of mathematicians for more than two thousand years. They are known as rectification and quadrature of the circle.

The secret key to these problems is the true value of the ratio of the circumference of a circle to its diameter. This ratio is constant, and is represented by the Greek letter Π, the initial of *peripheia*, whence our word periphery, the circumference of a circle, ellipse, or any regular curvilinear figure.

The earliest work giving an account of the many attempts to square a circle is that of J. E. Montucla, entitled, "*Histoire des Recherces sur la Quadrature du Circle*," Paris, 1754. He adds to the title, "A Book intended to make Known the Real Discoveries concerning the Celebrated Problem, and to serve as a Preventative against new attempts at its Solution." That he did not succeed in deterring mathematicians is shown in the many attempts of later years to solve the problem.

The great mathematician Archimedes, about 250 B. C., showed that the value of Π was less than $3\frac{1}{7}$ and more than $3\frac{10}{71}$. Antiphon, a contemporary with Archimedes, attempted to find the area of the circle by inscribing a square, then adding isosceles triangles in the four segments, then eight similar triangles in the remaining segments, and so on until the circle was exhausted. Sextus, a disciple of Pythagoras, claimed to have solved it. Aristophanes, in his "Comedy of the Clouds," ridicules Meton, of Metonic-Cycle fame, for endeavoring to find the value of Π. Eutocius tells us that Appollonius approached nearer the true ratio than Archimedes. Philo of Gadara surpassed his predecessors, his ratio differing from the accepted ratio by less than $\frac{1}{1000000}$. Anaxagoras, while in prison, spent much time on the problem. Hypocrates, of Chios, while searching for the ratio was led to the discovery of the exact area of the lune, known as the lune of Hypocrates, which was the first discovery of a space inclosed by curved lines of which we have any record. This lune is the space inclosed by the arc of a quadrant and the semicircle drawn externally upon the chord of the quadrant. The area of this lune is equal to that of the right triangle, whose legs are the radii of the circle, the hypotenuse being the diameter upon which the outer semicircle of the lune is drawn.

Cardinal de Cusa rolled a wheel upon a plane, and then measured the path of the revolution of the wheel. He made the ratio the $\sqrt{10} = 3.162 +$, the same as Thomas Hobbes, London, 1578. He believed with Charles Bovillus, of the next century, that the cycloid is the arc of the circle. In 1592, Joseph Scaliger published his Nova Cyclometria, giving the ratio, 3.14098 +.

Prof. Augustus de Morgan, in 1872, published his work, entitled, "A Budget of Paradoxes." In this work of 512 pages are mentioned the names of 75 writers on the subject of "Cyclometry." He reviewed the works of 42 of those writers, giving the results of their search for the value of Π, bringing the subject down to 1870. The entire list has been compiled and tabulated by S. C. Gould, Editor of "Notes and Queries," Manchester, N. H., and printed in a neat monogram, from which some of the above items have been drawn. It may be regarded as a remarkable fact that the compilation does not reveal the name of a single American author or book upon the subject of "Cyclometry."

Van Ceulen was one of the first to extend the numerical computation to a large number of decimals. The tedious method by which he worked out the result, extending his calculations to 36 decimals, was regarded so remarkable a feat that the result was engraven upon his tombstone.

The most remarkable computation made in modern times, considering the prodigious work involved, and the care required in such a labyrinth of figures to avoid an error, is the computation of Π to 707 places of decimals, by William Shanks, of London, England. He was assisted by Dr. William Rutherford in the verification of the first 441 decimals. After the publication of his former result of 607 decimals, 1853, Mr. Shanks found errors in the last 14 places. In correcting these errors he extended the decimals to 707 places, and this result is printed in the Proceedings of the Royal Society of London, Vol. XXI., 1873. We append the result of his computation to this article.

The method of finding the value of Π, as demonstrated in elementary geometry, is to inscribe a hexagon in a circle, one side being then equal to the radius, and then to find the side of a polygon of double the number of sides. This process may be repeated, and as each new inscribed polygon approaches more nearly to that of the circle, the approximation may be carried as far as desired. We append one demonstration, producing an interesting formula,

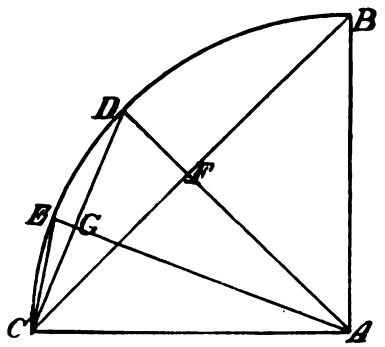
which we have not seen in print. It is to find the approximate value of Π by starting with an inscribed square.

Construct the quadrant ABC. Draw the radii, AD, AF, respectively, $\perp$ to the chords BC and DC.

BC is a side of the inscribed square; DC a side of the octagon

$\overline{BC}^2 = \overline{AC}^2 + \overline{AB}^2 = 2R^2$. Whence $BC = R\sqrt{2}$, and $AF = \frac{1}{2}R\sqrt{2}$.

Hence, $DF = R - \frac{1}{2}R\sqrt{2}$, and $\overline{DF}^2 = 3\frac{R^2}{2} - R^2\sqrt{2}$.
But $\overline{CD}^2 = \overline{CF}^2 + \overline{DF}^2 = 2R^2 - R^2\sqrt{2}$, and $CD = R\sqrt{2 - \sqrt{2}}$.



To find CE, we have $\overline{CG}^2 = \frac{1}{4}\overline{CD}^2 = \frac{R^2}{2} - \frac{R^2}{4}\sqrt{2}$,
and $\overline{AG}^2 = \overline{AC}^2 - \overline{CG}^2 = \frac{R^2}{2} + \frac{R^2}{4}\sqrt{2} = \frac{R^2}{4}(2 + \sqrt{2}.)$

Hence, $EG = R - \frac{R}{2}\sqrt{2 + \sqrt{2}}$,
and $\overline{EG}^2 = 3\frac{R^2}{2} + \frac{R^2}{4}\sqrt{2} - 2\sqrt{2 + \sqrt{2}}$.

Hence $\overline{CE}^2 = \overline{CG}^2 + \overline{EG}^2 =$

$$2R^2 - R^2\sqrt{2 + \sqrt{2}}.$$

$CE = \sqrt{2 - \sqrt{2 + \sqrt{2}}}$, R being unity.

$4BC =$ perimeter of the square $=$ polygon of 2^2 sides $= 4R\sqrt{2}$.

$8\,CD =$ perimeter of 2^3 sides $= 2^3 R \sqrt{2 - \sqrt{2}}.$

$16\,CD =$ " " 2^4 " $= 2^4 R \sqrt{2 - \sqrt{2 + \sqrt{2}}}.$

Finally " " 2^n " $= 2^n R \sqrt{2 - \sqrt{2 + \sqrt{2 \ldots\ldots n}}}.$

If $n = 7$, we have

$$2^7 \times \sqrt{2 - \sqrt{2 + \sqrt{2 + \sqrt{2 + \sqrt{2 + \sqrt{2 + \sqrt{2}}}}}}} =$$

$$128 \times .024543 = 3{,}1415 \times$$

When $n =$ infinity, the expression gives the value of π.

Hence $\Pi = 2^n \sqrt{2 - \sqrt{2 + \sqrt{2} + \ldots}}$ n terms, n being infinity. In this expression each radical sign extends over all the following terms.

Many formulæ have been deduced for finding the value of Π, and some of these are very peculiar.

John Bernouilli showed that $\Pi = \dfrac{\log_e(-1).}{\sqrt{-1}.}$

This formula may be proved as follows:

Leonard Euler showed that

$$\sin\varphi = \frac{e^{\varphi\sqrt{-1}} - e^{-\varphi\sqrt{-1}}}{2\sqrt{-1}} \ldots\ldots\ldots\ldots\ldots(1),$$

and $$\cos\varphi = \frac{e^{\varphi\sqrt{-1}} + e^{-\varphi\sqrt{-1}}}{2} \ldots\ldots\ldots\ldots\ldots(2).$$

Dividing (1) by (2) and putting $\varphi = \frac{\pi}{4}$, since the equation is true for all values of φ, we obtain

$$\sqrt{-1} = \frac{e^{\frac{\pi\sqrt{-1}}{2}} + 1}{e^{\frac{\pi\sqrt{-1}}{2}} - 1} \ldots\ldots\ldots\ldots\ldots(3).$$

From (3), we obtain

$$e^{\pi\sqrt{-1}} = -1, \text{ or } e = (-1)^{\frac{1}{\pi\sqrt{-1}}}$$

The latter equation may be written

$$e^{\frac{\Pi\sqrt{-1}}{2}} = \sqrt{-1}.$$

Taking the $\sqrt{-1}$, gives

$$e^{-\frac{\Pi}{2}} = (\sqrt{-1})^{\sqrt{-1}} = .207879 +,$$

which is a case of an imaginary expression apparently having a finite result. Prof. Benjamin Pierce terms this "the mysterious formula."

Again, clear (3) of fractions, transpose, and factor, we find

$$e^{\frac{\Pi\sqrt{-1}}{2}}(1 - \sqrt{-1}) = 1 + \sqrt{-1};$$

whence $e^{\frac{\Pi\sqrt{-1}}{2}} = \sqrt{-1}$, and $e^{\Pi\sqrt{-1}} = -1$

$$\therefore\ \Pi\sqrt{-1} = \log_e(-1).$$

and $$\Pi = \frac{\log(-1)}{\sqrt{-1}}.$$

Bernouilli also showed that $\frac{\pi^2}{6} = 1 + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \frac{1}{5^2} +$, etc. $\frac{\Pi^4}{90} = 1 + \frac{1}{2^4} + \frac{1}{3^4} + \frac{1}{4^4} + \frac{1}{5^4} +$, etc. $\frac{\Pi^6}{945} = 1 + \frac{1}{2^6} + \frac{1}{3^6} + \frac{1}{4^6} + \frac{1}{5^6} +$, etc. $\frac{\Pi^2}{8} = 1 + \frac{1}{3^2} + \frac{1}{5^2} + \frac{1}{7^2} +$, etc. (Todhunter.)

De Morgan deduced the formula,

$$\Pi = 4\left(1 - \tfrac{1}{3} + \tfrac{1}{5} - \tfrac{1}{7} + \tfrac{1}{9} - \text{etc.}\right).$$

Wallis, in his "Arithmetic of Infinities," 1655, shows that

$$\Pi R^2 : D^2 :: 1 : \frac{9 \times 25 \times 49 \times \text{etc.}}{8 \times 24 \times 48 \times \text{etc.}}$$

This gives $\Pi = 4 \times \frac{8 \times 24 \times 48 \ldots}{9 \times 25 \times 49 \ldots}$

In this equation the denominators are the squares of the odd numbers in their order, and each numerator is one less than its corresponding denominator.

The Integral Calculus gives the following simple expression in terms of a definite integral:

$$\frac{\Pi}{2} = \int_0^{\infty} \frac{dx}{1+x^2} = 1.57079632+$$

The late Charles Latimer, Cleveland, O., produced the following parallactic equation:

Parallactic $\Pi = 5\sqrt{\Pi} = 8''.862$. S. C. Gould took the mean of 29 calculations, which includes the famous mathematicians who have computed the solar parallax, and he finds the average to be $8''.862+$, the results agreeing to three decimal places.

The fraction $\frac{355}{113}$ is a close approximation for Π, giving its value correct to six decimal places.

Thomas P. Stowell has produced from the digits the fraction,

$$\frac{67389}{21450} = 3.1416$$

The formula,

$$\frac{\Pi}{4} = 2\tan^{-1}\tfrac{1}{3} + \tan^{-1}\tfrac{1}{7},$$

was employed by Clausen of Germany in computing the value of Π. Dase, also of Germany, used the formula,

$$\frac{\Pi}{4} = \tan^{-1}\tfrac{1}{2} + \tan^{-1}\tfrac{1}{5} + \tan^{-1}\tfrac{1}{8}.$$

These computations, carried on independently, and extended to 200 decimal places, agreed to the last figure.

Rutherford used the formula,

$$\frac{\Pi}{4} = 4\tan^{-1}\tfrac{1}{5} - \tan^{-1}\tfrac{1}{70} + \tan^{-1}\tfrac{1}{99}.$$

Machin's formula,

$$\frac{\Pi}{4} = 4\tan^{-1}\tfrac{1}{5} - \tan^{-1}\tfrac{1}{239},$$

is more noted for computing the value of Π.

CONSTANTS.

Common logarithm of $\Pi = 0.4971498726941338543 5 +$
Naperian " $\Pi = 1.1447298858494001741 4 +$
Reciprocal of $\Pi = 0.3183098861837906715377 67 +$
Square of $\Pi = 9.8696044010893586188344909 +$
Square root of $\Pi = 1.7724538509055160272981674 +$
Naperian base $e = 2.7182818284590452353602 87 +$
Common logarithm of $e = 0.4342944819032518276511289 +$

The following is William Shanks' value carried to 707 decimals;

$\Pi =$ 3.141592 653589 793238 462643 383279 502884
197169 399375 105820 974944 592307 816406 286208 998628
034825 342117 067982 148086 513282 306647 093844 609550
582231 725359 408128 481117 450284 102701 938521 105559
644622 948954 930381 964428 810975 665933 446128 475648
233786 783165 271201 909145 648566 923460 348610 454326
648213 393607 260249 141273 724587 006606 315588 174881
520920 962829 254091 715364 367892 590360 011330 530548
820466 521384 146951 941511 609433 057270 363759 591953
092186 117381 932611 793105 118548 074462 379834 749567
351885 752724 891227 938183 011949 129833 673362 441936
643086 021395 016092 448077 230943 628553 096620 275569
397986 950222 474996 206074 970304 123668 861995 110089
202383 770213 141694 119029 885825 446816 397999 046597
000817 002963 123773 813420 841307 914511 839805 70985 ±.

OBITUARY.

JOSEPH PRACY, M. E., '81.

JOSEPH PRACY, whose death occurred on July 22, 1891, was born in San Francisco, Cal., on November 18, 1854.

His preparatory education was obtained in the schools of San Francisco, passing successively through the Lincoln Grammar and Boy's High Schools and the Pacific Business College. He then entered the machine shop of Messrs. Walkington and Kidd. After serving his apprenticeship, he continued in the employ of the same firm, and was advanced through different positions to that of Superintendent.

Having a strong desire to take a thorough course in the theoretical studies of his profession, he came east in December, 1876, and entered the Stevens School, from which he passed into the Stevens Institute in the fall of 1877. He graduated in 1881, receiving the degree of Mechanical Engineer.

His record, as a student, was excellent, and he took an active interest in all the work of the Athletic Association, being, for a long time, a member of the Executive Committee.

He returned to San Francisco in October, 1881, and started a machine shop, which he equipped with modern tools, many being purchased from the largest firms in the east, who manufacture machine tools. His business success was gratifying, and a successful professional career was within his grasp.

In September, 1888, the shop was destroyed by the fire which consumed a large section of the city. As soon as the ruins were cooled he commenced clearing away the debris, and erected a brick building on the site of the machine shop. In this work he was so

active that the new shop was the first building erected and equipped for work in the burned district.

Success again attended his efforts, but the demands of business increased so rapidly that he was unable to take the necessary rest which his health demanded. This intense and prolonged application aggravated a trouble of the heart, of long standing, which was the direct cause of his death.

His integrity and sterling qualities of character were recognized and appreciated by all his college mates and business associates, as evidenced by the many sincere and outspoken expressions of sympathy for his family, and regret that one so upright in his life should be thus cut off in early manhood.

In 1883 he was married to Miss S. A. Idell, of Hoboken, N. J.

The funeral services were held at his late residence in San Francisco, and the remains were reverently laid at rest in a cemetery in his native city.

GEORGE LYMAN BALDWIN.

GEORGE LYMAN BALDWIN died at Litchfield, Conn., on October 3, 1891, at the age of 26 years. Mr. Baldwin was an instructor for two years in the junior class of the Stevens School.

ATHLETICS.

All over the country in all the colleges, the foot-ball season has commenced. On every campus the brawny athletes are "rushing," and "tackling," and "falling on the ball." In every college hall, among every knot of men, the subject holds first place, and the heart of every man beats high with hope that he may be one of the chosen eleven, to win fresh laurels for his Alma Mater. And it is with pleasure that the Indicator goes forth this month, to the Alumni and friends of Stevens, bearing the tidings that her venerable walls, which have so often re-echoed praises for success in her chosen profession, shall soon ring with the cheers of her sons, as they celebrate her victories on the athletic field. For the coolness, pluck and muscle which we noted in the class games last fall, have at last borne fruit, and the team which represents Stevens this year is one that shall again bring victory to the "Crimson and the Gray."

As yet it is too early to estimate the strength ot the teams we shall have to face in the league; but good judges have given it as their opinion that our chances for the pennant are very bright, and that even at the worst we ought not fall behind second place. The games played so far have not brought out the full strength of the team, and we shall not know what it can do until we tackle Cornell on the 17th.

Captain Mackenzie has had an abundance of material to pick from, and a very strong, well organized scrub to give practice to the team. The only weak spot now is at center rush, and the man for this position has not been chosen. The other positions will probably be filled as follows: Mackenzie and Hake, half backs; Strong, quarter; Coyne and Griswold, ends; W. Cuntz and Hutcheson, tackles; C. Mackenzie and Schumacher, guards. Terry, a brother of Wyllis Terry, the Yale half back, is trying for full back, and the man who fills this position will be a good player. Maynard and Fielder will be the substitute backs, and Woodward, Lord, or Greenidge, fill any vacancies in the line.

It is with regret that we turn from the consideration of this bright prospect to obey the hint of the treasurer of the Athletic Association, and call the attention of the students to financial matters. We desire to impress the fact upon every man in college, who is able to stand the expense, that it is an imperative duty he owes the college, his fellow students, and his friends, to join the "Association," and contribute his quota toward the support of the teams. Only about $200 was left over from last year, and all additional expenses, to say nothing of rent, will have to come out of the dues of members of the Association. We are going to have a good foot-ball team this year—a team which will win victories—a team which every man in college will be glad to talk about, and whose games he will be glad to bring his sister or chum, or somebody else's sister to see. When

that day comes let every man be able to show his membership ticket, and have the satisfaction of saying to himself, "this is the team which I helped to put in the field."

THE annual meeting of the "Eastern Intercollegiate Foot-ball Association" was held in Boston, October 7. Stevens, through her delegates, Capt. W. P. MacKenzie and Manager W. T. Hill, applied for readmission to the league, and claimed the right to take part in the deliberations. This was not conceded, and the league proceeded to transact its regular business. Then the question of Stevens' readmission came up, and was decided upon favorably, Technology and Amherst voting for us, and Bowdoin, as arranged last year having no vote. This made six colleges in the league, and all attempts to arrange a schedule resulted in a tie; Stevens, Amherst and Technology voting one way, and Williams, Dartmouth and Bowdoin the other. Finally Dartmouth, in return for Stevens' support on the schedule, voted with Amherst and Technology to transfer Bowdoin's dates to Stevens, and Bowdoin, left in the anomalous position of being a member of the league, but with no games to play, resigned.

Great praise is due to Messrs. Hill and Mackenzie for the skill and tact with which they conducted the negotiations.

The schedule of the Eastern Intercollegiate Foot-ball Association is as follows:

Oct. 31, Stevens *vs.* Williams, at Williamstown.
" 31, Amherst *vs.* Technology, at Boston.
Nov. 4, Stevens *vs.* Dartmouth, at Hoboken.
" 7, Williams *vs.* Technology, at Williamstown.
" 7, Amherst *vs.* Dartmouth, at Hanover.
" 14, Williams *vs.* Dartmouth, at Hanover.
" 14, Stevens *vs.* Amherst, at Amherst.
" 20, Williams *vs.* Amherst, at Amherst.
" 21, Dartmouth *vs.* Technology, at Boston.
" 26, Stevens *vs.* Technology, at Hoboken.

Besides these league games the management has arranged practice games as scheduled below, and has also under consideration challenges from West Point, Orange Athletic Club, Crescent Athletic Club, etc.

Oct. —, Stevens *vs.* N. Y. A. C., at Hoboken. Score: Stevens, 6; N. Y. A. C., 5.
Oct. 10, Stevens *vs.* N. Y. University, at Hoboken. Score: Stevens, 38; N. Y. U., 0.
Oct. 17, Stevens *vs.* Cornell, at Ithaca. Score: Stevens, 0; Cornell, 72.
" 21, " " Columbia, at Hoboken. Score: Stevens, 52; Columbia, 0.
" 24, " " Rutgers, at New Brunswick.
" 28, " " N. Y. A. C., at Hoboken.
Nov. 11, " " Rutgers, at Hoboken.
" 18, " " M. A. C., at Hoboken.

THE annual cane rush between the Sophomore and Freshman Classes came off at the St. George Cricket Grounds, Monday, October 5. The Freshmen proved superior in weight and members, and won their right to carry canes, by a score of 16 hands to 13.

THE Freshman foot-ball team, comprising most of last year's Stevens School championship team, has proved itself remarkably strong. The first game played was won from the Senior team of the Montclair Athletic Club, by a score of 26—0. October 17, they play the Junior team of the Orange Athletic Club. They have challenged the Princeton Freshmen.

THE Sophomore team will not begin practicing until after the examinations on October 21, as several members have conditions to be worked off. The annual game with the Freshmen will probably come off in about three weeks, and promises to be unusually close and exciting.

INSTITUTE NOTES.

THE AMERICAN RAILWAY MASTER MECHANICS ASSOCIATION SCHOLARSHIPS. At the Annual Convention of this Association, held last year, a committee was appointed to confer with different engineering schools of the country to ascertain what arrangements could be made to establish scholarships for the benefit of sons of members of the Association. The Association had a fund of about $8,000, which it desired to devote to this purpose.

The committee reported at the Annual Convention, held in June of this year, recommending the acceptance of the offer made by the Stevens Institute.

By the contract entered into between the Trustees of the Institute and the American Master Mechanics Association, a corporation under the laws of the State of New York, the latter are entitled to four perpetual scholarships for each and every year, for the exclusive use of such pupils as may be designated by them, the educational qualifications to be determined by the Institute authorities, who shall assign applicants according to seniority and rank.

For the first year the Association will have one scholarship at its disposition in each of the four classes of the Institute, and thereafter one each year for the full course.

Vacancies will be filled by appointment for the unexpired terms. These scholarships will begin this year. Candidates for them must be the sons of members or of honorary members of the American Master Mechanics Association in good standing, or the sons of deceased members who died in good standing. They must also have worked for at least one year in a recognized machine shop.

AMONG THE PAPERS PRESENTED to the Mechanical Science and Engineering Section of the Am. Asso. for the Adv. of Science, at the Washington meeting, in August, 1891, were the following:

"Note on the Efficiency of the Screw Propeller."

"On a Method of Holding Samples of Wood and Brick for Determination of Tensile Strength."

"Relative Economy of Compound and Triple Expansion Engines."—By Prof. Denton.

"Maximum Error due to Neglecting the Radiation Correction of a Barrus Universal Calorimeter."

"Relative Economy of Carbonic Acid as the Working Fluid of Refrigerating Machines."—By Prof. Jacobus.

At this meeting Professor Webb was appointed a member of the Nominating Committee of the Mech. Sci. and Engineering Section for the next meeting.

A SHORT ARTICLE on "The Rotation of the Earth on its Axis," by Professor Wood, appeared in *The Mechanical News*, of September 1, 1891.

THE TRUSTEES OF THE INSTITUTE have been invited to consider a proposition of the Carriage Builders' National Association of the United States to establish a connection between the Institute and the Technical School conducted in New York City under the auspices of this association. The idea suggested is to extend the course of the school, heretofore confined to draughting, to include instruction upon other technical subjects that have a bearing upon carriage manufacture.

PROF. MAYER AND PROF. LEEDS returned from abroad at the end of the summer vacation, having spent about three months traveling on the continent. They visited different points of interest in Germany, Holland, and Belgium, and went as far South as Switzerland.

PROF. WOOD spent the summer at Saratoga Springs, New York.

PROF. JACOBUS has presented the Institute with a complete set of taps and dyes for cutting V and square threads of the Whitworth form.

The Freshman class numbers sixty-nine members, of which the following is a list:

Percy Allan, Montclair, N. J.
Benj. Andrews, New Orleans, La.
Pearson Arrison, Newark, N. J.
B. C. Ball, Elizabeth, N. J.
D. D. Barnum, Danbury, Conn.
H. Benedict, Montclair, N. J.
Edgar Boody, Brooklyn, N. Y.
L. J. Borland, Bergen Point, N. J.
Wm. J. Burnett, Brooklyn, N. Y.
Thos. E. Butterfield, Jersey City, N. J.
Frank E. Brackett, Cumberland, Md.
Willard Brown, Newark, N. J.
G. E. Bruen, Brooklyn, N. Y.
L. Carter, E. Orange, N. J.
Chas. T. Church, New York City.
Stuart Cooper, Morristown, N. J.
C. A. Leyton, Montclair, N. J.
A. A. Lowenstein, New York City.
F. N. MacVeety, Brooklyn, N. Y.
Geo. S. Montgomery, Sedalia, Mo.
Sam'l H. Neuburger, New York City.
Gus T. Nisbet, Nashville, Tenn.
Fred. D. Ogden, Brooklyn, N. Y.
Edw. Olmsted, Elizabeth, N. J.
Chas. P. Paulding, Cold Spring, N.Y.
W. G. Raoul, Jr., New Brighton, S. I.
Edw. W. Robinson, New York City.
Otto B. Schalk, Newark, N. J.
Edw. C. Schmidt, Jersey City, N. J.
Alfred Siegfried, Jersey City Hgts.
Chas. J. Slipper, Brooklyn, N. Y.
F. R. Smart, Jr., Flushing, L. I.

Wm. H. Corbett, Brooklyn, N. Y.
Thos. B. Cuming, Englewood, N. J.
Edwin B. Decker, Jr., Somerville, N. J.
C. K. Duncan, Jr., Montgomery, Ala.
Jos. F. Dupuy, Jr., St. Gabriel, La.
Jno. Fayerweather, Paterson, N. J.
C. A. Greenidge, Barbadoes, W. I.
Richard Gunagan, Rutherford, N. J.
A. K. Hamilton, Johnstown, Pa.
Edw. M. Harrison, Jr., Montclair, N. J.
Guy Hopkins, New Orleans, La.
Edwin Hutchinson, Brooklyn, N. Y.
Bethel W. Jackson, E. Orange, N. J.
T. E. Jewell, Brooklyn, N. Y.
E. Kemble, E. Orange, N. J.
W. D. Kirker, Paterson, N. J.
H. J. Koehler, Jr., Long Island City.
F. V. Lawrence, S. Orange, N. J.
A. Lennsen, Jr., New York City.
T. W. F. Smith, New York City.
M. H. Spear, Brooklyn, N. Y.
H. A. Stillwell, Brooklyn, N. Y.
A. C. Sumner, Brooklyn, N. Y.
Fred'k N. Taff, Millington, N. J.
Gray Torrey, Sterling, N. J.
G. L. Townsend, New York City.
F. K. Vreeland, Orange, N. J.
F. W. Walker, Flatbush, N. Y.
R. T. Walker, Flatbush, N. Y.
Wm. W. Ward, New York City.
Wallace Willett, E. Orange, N. J.
A. R. Williams, Wilmington, N. C.
Jno. R. Williams, Jr., Newark, N. J.
Victor A. Wood, Hoboken, N. J.
A. C. Woodward, Bayonne City, N. J.
A. E. Woolsey, Jersey City Heights.
H. C. Zimmermann, Newark, N. J.

The following new candidates were admitted to the Sophomore Class:

E. J. Burke, Alexander, Va.
J. B. Hamilton, Petersburg, Va.
R. P. Hamilton, Petersburg, Va.
Gilbert Rosenbusch, New York City.

SHIGERU MATSUDA, who attended the Junior Class one term last year, and then left to enter the drawing office of the William Sellers Company, of Philadelphia, has now rejoined the Junior Class.

THE TOTAL MEMBERSHIP of the Institute this year is 217. Of this number 40 are Seniors, 51 Juniors, 57 Sophomores and 69 Freshmen.

PROF. JACOBUS will lecture on "Experimental Illustrations of the Principles and Properties of Substances Applied in Modern Refrigerating Machines," at the Franklin Institute, Philadelphia, on February 5, 1892.

This is one of the lectures of the series arranged by the Franklin Institute for the season of 1891–92.

THE USUAL REPAIRS of renovating rooms have been made during the summer vacation. The most extensive alteration was made in the basement of the main building, where the large brick piers have been removed and iron columns substituted for them. Additional room has thereby been gained, and the space is now better lighted, and is well adapted for the exercises in experimental mechanics, for which the apparatus has been permanently located.

NINETY-FOUR CANDIDATES applied for admission to the class of '95; seventy of these attended the Stevens School.

PROF. MAYER purchased a horse-shoe magnet while abroad, which will support over ten times its own weight. The magnet weighs about nine pounds.

THE ATTENDANCE in the Stevens School continues to increase each year. The number of pupils enrolled on October 15 was 239, which is more than last year, notwithstanding that the Preparatory Class has been discontinued. Allowing for accessions during the year, the attendance before the close will be over 250.

The School, as now graded, consists of the Junior, Lower Middle, Upper Middle and Institute Preparatory Classes, and provides for a three-year preparatory course. The Institute Preparatory, and the Upper Middle Classes, prepare students for entrance to the Institute. There are now two divisions of the Upper Middle Class, two of the Institute Preparatory, three of the Lower Middle, and two of the Junior.

The growth of the School has been so rapid that all the rooms in the spacious building, erected only three years ago, are now occupied. The large lecture hall has been divided into two rooms by means of rolling partitions, so as to accommodate two classes. Four new instructors have been appointed this year, two to fill vacancies caused by the resignations of Messrs. Baker and Baldwin, and two to take charge of new divisions.

The new appointees are: Messrs. G. H. Roberts, C. I. Whitman, J. Frank Yawger and C. D. White.

"STEVENS LIFE," the bi-weekly publication of the undergraduates, appears regularly, containing full accounts of the athletic sports and other Institute events of interest to undergraduates.

The appearance of the publication has been improved by a new design on first page of cover.

The Editors of "LIFE" are: F. H. McGahie,'92, Ed.-in-Chief; F. D. Furman, '93, Business Manager; J. B. Klumpp, '94; H. D. Lawton, '94; W. B. Field, '94; L. Lyndon, '94; A. K. Hamilton, '95; W. H. Corbett, '95.

THE FOLLOWING ARE THE OFFICERS of the Engineering Society for the current year; A. W. Patterson, Pres.; F. W. Gardiner, V.-Pres.; A. R. Hake, Sec.

THE election of officers for the several classes resulted as follows:

Class of '92.—President, Howard Guerney; Vice-President, Louis Wettlaufer; Secretary, Fred. Gardiner; Historian, Wm. Powell.

Class of '93.—President, F. D. Furman; Vice-President, A. E. Merkel; Secretary, Mors O. Slocum; Treasurer, A. Schumacher; Historian, John Paulsen.

Class of '94.—President, R. E. Hall; Vice-President, F. J. Angell; Secretary, Jos. G. Crowell; Treasurer, F. M. Oppermann; Historian, H. D. Lawton.

Class of '95.—President, George Montgomery; Vice-President, W. G. Raoul, Jr.; Secretary, T. E. Jewell; Treasurer, C. P. Paulding; Historian, W. W. Ward; Class Poet, B. H. Jackson.

INSTITUTE PERSONALS.

'76.

WILLIAM KENT, Secretary of the Mechanical Science and Engineering Section of the American Association for the Advancement of Science for 1890–91, presented papers at the Washington meeting, in August, "On the Efficiency of the Steam Jackets of the Pawtucket Pumping Engine," and "On the Opportunity for Mechanical Research at the World's Fair."

Mr. Kent will lecture, December 4, before the Franklin Institute, Philadelphia, on "Some of the Preventable Wastes of Heat in the Generation of Steam."

PHILIP E. RAQUE has applied for membership in the American Society of Mechanical Engineers.

'82.

THE ADDRESS of Pierce Butler is 1803 First Street, Louisville, Ky.

'83

ERNEST N. WRIGHT of Westinghouse, Church, Kerr & Co., desires to complete his set of numbers of the INDICATOR, and will be glad to hear from any alumnus who can supply him with Nos. 7 and 9 of Vol. II., and Nos. 1 to 5 of Vol. III.

'84.

THE *Street Railway Journal* OF JULY, 1891, contains an illustrated article by Frank Van Vleck, describing the San Diego Cable R. R.

IN THE REPORT of the Proceedings of the Annual Alumni Meeting, as published in the July issue of the INDICATOR, the list of Officers of the Alumni Association for the current year did not include the name of the Corresponding Secretary. Mr. Wm. L. Lyall was elected Corresponding Secretary, to succeed Mr. F. E. Idell; his address is 540 West Twenty-third Street, New York City.

LAFAYETTE D. CARROLL has recently returned to New Orleans, La., after a two years' absence in Mexico. He has opened an office at 47 Carondelet Street, New Orleans, La.

'86.

LEONARD G. PAINE is located with the Pratt & WHITNEY Co., Hartford, Conn.

'87.

WM. E. SCHOENBORN has made application for Junior Membership in The American Society of Mechanical Engineers.

FRANKLIN MOELLER, Draughtsman with Webster, Camp & Lane, Akron, O., has applied for Junior Membership in the American Society of Mechanical Engineers.

ROB'T M. ANDERSON started early in July for an extended tour in Europe. When last heard from, he had traveled through France, and as far south as Florence, Italy, and thence through Switzerland. He will continue through a part of Austria, and in returning, visit the principal cities of Germany, and finally, spend several weeks in Paris and London.

'88.

P. A. DOTY, Assistant Superintendent, Union Gas Improvement Company, Paterson, N. J., has applied for Junior Membership in the American Society of Mechanical Engineers.

J. M. FERRIS was appointed Superintendent and Engineer Maintenance of Way for the Toledo, Columbus and Cincinnati Railway in July last, with office at Kenton, O.

EMBURY McLEAN is about to introduce electric fans into the Trans-Atlantic steamer "Elbe."

T. A. VAN DER WILLIGEN is temporarily located with the Chicopee Gas Works, Chicopee, Mass.

THOS. TAYLOR, JR., is Superintendent of the Orangeburg Oil Mill Co., at Orangeburg, S. C. This firm manufactures crude cotton-seed oil, cake, meal, re-gins, hull ashes and ammoniated fertilizers.

'89.

WILLIAM C. HAWKINS, until recently Assistant Engineer of Construction, Third Avenue Cable Railroad, New York City, is an applicant for Junior Membership in the American Society of Mechanical Engineers.

C. A. WILLIS has left the employ of the Pennsylvania Steel Company, and is now with R. D. Wood & Co., Camden Iron Works, Philadelphia, Pa.

ROBERT G. SMITH is a Junior in Harvard University.

'90.

W. F. LAWRENCE is in the employ of the Derby Gas Company, Birmingham, Conn. Communications addressed to Box 112, Birmingham, Conn., will also reach him.

E. H. PEABODY is with the Babcock & Wilcox Co., 30 Cortlandt Street, New York City.

WALTER F. PHELPS is with the Dayton Fan and Motor Company' Dayton, O.

F. THUMAN is connected with the Natural Gas Light and Fuel Company, builders of water gas works, 52 Lake Street, Chicago, Ill.

E. E. HINKLE is the engineer of the Union Iron Works, 29 Broadway, New York City.

LEONARD D. WILDMAN has applied for Junior Membership in the American Society of Mechanical Engineers.

'91.

C. G. ATWATER is in the draughting office of Robert Dralle, civil engineer in Stralan-bei-Berlin, and is now taking part in the erection of a glass furnace in the village of Helmstedt, Braunschweig, Germany.

JULIUS OELBERMANN is with Bement, Miles & Co., Philadelphia, Pa.

'91.

ARDEN POST AND ANTHONY KENNEDY are in the employ of the Baltimore and Ohio Railroad, at the Mt. Clare shops, Baltimore, Md. They have been assigned to duty inspecting materials.

JESSE A. DAVIS is in the draughting office of the Baltimore and Ohio Railroad, Mt. Clare shops, Baltimore, Md.

BENJAMIN W. CARLL has accepted a position with the Dame & Townsend Company, 76 John Street, New York City.

GEO. C. HOLBERTON is employed by the Edison Machine Works, Schenectady, N. Y.

F. T. GAUSE AND ARDEN POST presented a paper on "The Economy Produced by the Use of Water Injected as a Fine Spray into Air Compressors," at the Washington meeting of the A. A. for the Adv. Science. The paper is based upon tests made by the writers for their graduating thesis.

JOHN DARBY is in the Draughting Department of the Washington Navy Yard, Washington, D. C.

W. S. BUVINGER is in the Engineers' Department of the Pittsburgh Iron and Steel Engineering Company, Pittsburgh, Pa.

JULIAN C. SMITH had a severe attack of bilious fever, which compelled him to resign his position with the Florida Phosphate Company, at Ocala, Fla. He has recently accepted a position in the Mill Department of the West Virginia and Pittsburgh Railroad, Lane's Bottom, Webster Co., W. Va.

GEO. F. SUMMERS' address is 645 North Twelfth Street, Philadelphia Pa.

GEO. L. MANNING has accepted the position of Instructor in Mathematics and Drawing at the Adelphi Academy, Brooklyn, N. Y.

WM. S. ACKERMAN is in the employ of The Stearns-Roger Manufacturing Company, Denver, Col. This firm's principal business is the preparation of designs of complete power plants for mines.

'93.

A. W. RÖLKER is taking a special course in chemistry with Dr. Stillman, having been obliged to discontinue the Institute course on account of weak eyes.

'94.

DAL MOLIN, who was taken ill at the close of his Freshman year, has also decided to take a special course in chemistry.

THE COLLEGE WORLD.

OBERLIN is the first college to introduce the idea of the Grecian Olympiad into the athletic contests.

THE RUSSIAN GOVERNMENT appropriated last year $15,400,000 for educational purposes, and $150,000,000 for the army,—ten times as much for war as for education.

WESTMINSTER COLLEGE, New Wilmington, Pa., has six students from Siam, sent there by the Government of that country.

WHILE the college men of the United States are but a small fraction of 1 per cent. of the voters, they hold 58 per cent. of the highest offices.

DANIEL P. BALDWIN, of Logansport, Ind., has offered a prize of $100 to the student of any college who will prepare the best essay on the subject, "The Merits and Defects of the McKinley Tariff Act of 1890," before April 15, 1892.

THE LELAND STANFORD UNIVERSITY, at Palo Alto, Cal., has a campus containing about 70,000 acres, with a driveway seventeen miles long.

IN the cane rush, at Lehigh, the Sophomores were victorious, '94 having 15 hands, and '95 having 13.

NORTHWESTERN UNIVERSITY will have in the neighborhood of 2,300 students the coming session.

ANDOVER has over 400 students, the largest number in its history.

AMONG some of the promising candidates for positions back of the line on Williams' foot-ball eleven are two sons of James A. Garfield.

IT is reported that William Waldorf Astor intends to endow with a million dollars a negro university at Oklahoma.

IT is claimed that there were more colleges in proportion to the population in the year 1100 than there are at the present time.

HARVARD.

THE HARVARD CORPORATION has created twenty new scholarships of $150 each, for needy students of the graduate school.

A REMARKABLE VOLUME will soon be presented to the university library. It contains manuscript copies of all the commencement programmes of the college from 1780 to 1890, and specimens of the order of commencement exercises at intervals from the first graduation in 1642 to the Revolutionary war.

THERE are sixty candidates for the Freshman foot-ball team.

HARVARD has lost five of last year's foot-ball team—Cumnock, Cranston, P. Trafford, Finlay, and Dean.

CAPTAIN DEAN, of last year's base-ball nine, will also be missed. Lewis R. Frothingham was chosen captain in his place.

CORNELL.

EX-PRESIDENT WHITE has offered to give $10,000 for an Alumni Hall, if the alumni raise $50,000 within six years.

THE FRESHMAN CLASSES at Harvard and Cornell number, respectively, 450 and 500 men.

YALE.

T. L. McCLUNG, of Knoxville, Tenn., was elected captain of the Yale University base-ball nine for the ensuing year.

THE FRESHMAN CLASS numbers 540; this being a gain of more than 100 over last year's class.

PRINCETON.

THERE will enter the Class of '94, at Princeton, next fall, a gentleman 53 years of age. During the Civil War he was in the Sophomore year, and then volunteered. He now intends to return and complete the course.

PROF. OSBORN presented a club house to the Athletic Association, for the use of the various athletic teams when in training.

PRINCETON will send out its ninth geological expedition this summer, to make research in the West.

TRINITY UNIVERSITY.

THE MANHATTAN ATHLETES have not been doing badly in England, though perhaps they have not quite come up to expectations. At Huddersfield they did not show their true form, as the track was rough, and they had not quite got over the effects of the voyage. They did better at the Manchester meeting of the English crack athletes. Cary won the 100-yard championship challenge cup. The half-mile flat race went to an Englishman, but the quarter-mile was won by Remington, the hammer throwing by Queckberner, both of the Manhattans. Their performances in France the first week in July will be interesting.—*Trinity University Review.*

A HANDSOME TABLET has been presented to Trinity College by friends and admirers, commemorating Trinity's recent victory over the Yale nine in base-ball.

THE CANE RUSH at the Troy Polytechnic resulted in a defeat for the Freshmen, '95 having 11, and '94 having 14 hands, respectively.

MISCELLANEOUS.

THE YOUNGEST COLLEGE PRESIDENT in the country is F. A. Turner, of Lincoln University, in Nebraska. He is twenty-nine years old, and is now filling his position for the third year.

DR. STETSON, President of Des Moines (co-educational) College, has announced that students who fall in love with each other during the term, are violating college rules and are liable to severe discipline.

HEREAFTER the professors at Columbia College are to have a vacation of a year every seven years.

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